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**THERMAL DESORPTION/
ULTRAVIOLET PHOTOLYSIS
PROCESS RESEARCH, TEST AND
EVALUATION PERFORMED AT
JOHNSTON ISLAND FOR THE
USAF INSTALLATION
RESTORATION PROGRAM,
VOL I: TECHNICAL REPORT**

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FINAL REPORT

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) The objective of this effort was to examine the feasibility of using a thermal desorption/ultraviolet destruction technology to treat Herbicide Orange (HO)-contaminated soil at Johnston Island (JI), in the Pacific Ocean. This technology is not considered incineration, so it is attractive from a regulatory standpoint. The IT Corporation pilot-scale thermal desorption/ultraviolet photolysis (TD/UV) process was used to successfully treat 2180 pounds of soil contaminated with HO and 2,3,7,8-tetrachlorobenzo-p-dioxin (TCDD). The TD/UV process volatilizes organic compounds from the soil matrix (coral at JI); collecting the desorbed organic contaminants in a solvent; and treating the contaminant-laden solvent with high-intensity UV photolysis. The desorption process occurs between 850 to 1150 degrees F. under a nitrogen atmosphere to prevent combustion. Samples of the JI feedstock and test-treated soil were sent to two laboratories for analysis of dioxin concentrations. Analysis of feedstock showed 2,3,7,8-TCDD levels ranged from 34-57 parts per billion (ppb). Concentrations in the treated soil ranged from 0.1 to 0.24 ppb and the sum of all dioxin/furan (Cont'd. on reverse)					
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condensers was less than 1 ppb, the Air Force test criterion. The TD/UV process demonstrated the capability to treat dioxin-contaminated soil and may be considered for full-scale soil restoration at USAF HO sites. Full-scale TD/UV system development was considered and used to estimate the cost of treatment of the JI site. This demonstration, when considered in context of the demonstration of this process at another HO site at the Naval Construction Battalion Center, Gulfport MS, shows the capability of the TD/UV process. This report is one of several reports encompassing the pilot-scale technology demonstrations on Herbicide Orange contaminated sites and is divided into four volumes. Volumes II-IV contain Appendixes A through Y which cover official correspondence, results of analyses and cost estimates for full-scale system development and service at Johnston Island.

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EXECUTIVE SUMMARY

In July 1986, the pilot-scale thermal desorption/ultraviolet (TD/UV) photolysis process developed by the IT Corporation (ITC) was used to successfully treat soil (coral), contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) at a former Herbicide Orange (HO) site at Johnston Island (JI), Pacific Ocean. JI, which is 625 acres and the largest island of a three-island atoll, approximately 720 nautical miles southwest of Honolulu, Hawaii. From 1972 through 1977, about 4 acres of the island were used to store 1.37 million gallons of HO in 55-gallon drums returned from Vietnam. The contamination resulted from earlier spills before the HO was destroyed in a separate program (PACER HO). The mobility and availability of this pilot plant provided a quick and inexpensive means of demonstrating the TD/UV photolysis process technology under field conditions as part of the research, test, and evaluation phase of the U.S. Air Force Installation Restoration Program.

The technology for the TD/UV photolysis process to decontaminate soil is based on use of volatilization to separate organic compounds, such as 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid, (2,4,5-T), and 2,3,7,8-TCDD, from a natural soil matrix; collecting the desorbed organic contaminants in a solvent, Soltrol[®]; and treating the contaminant-laden solvent using UV photolysis. Operating temperature in the thermal desorber is between 850 and 1100 °F. This desorption temperature range is significantly lower than incineration temperatures because thermal destruction by combustion is not required. Also, indirect heating is used, which results in an extremely low volume of noncondensable process emissions. Required soil temperatures and residence times depend on the volatility of the contaminants. The solvent circulation loop operates at less than 100 °F to reduce vapor pressure of the solvent and the adsorbed organic contaminants and to minimize the amount of organics remaining in the gas exiting the scrubber. Noncondensable gas is passed through a particulate filter and activated carbon adsorbers before its emission from a stack. The photochemical decomposition of organics in the solvent is related to UV light wattage and exposure time.

Four desorption test runs were conducted, processing 2180 pounds of dioxin-contaminated soil. Samples of the JI feedstock and treated soil and solvent were sent to two laboratories [IT Analytical Services (ITAS) and Battelle Columbus Laboratories] for analysis of dioxin concentrations. Analysis of soil feedstock samples showed that 2,3,7,8-TCDD ranged from 34 to 57 ppb, lower than originally intended for the demonstration. In three of the tests, the samples for treated soil showed residual 2,3,7,8-TCDD concentrations less than 0.1 ppb. The fourth test showed a detected concentration of 0.24 ppb. In all tests, the sums of the tetra through hexa congeners of polychlorinated dibenzo-p-dioxin (PCDD) and polychlorinated dibenzofuran (PCDF) were less than 1 ppb, the Air Force test criterion. These results show that the desorption process can satisfactorily treat coral-type soil feedstock with initial 2,3,7,8-TCDD concentrations, with a soil operating temperature at 1022 °F and soil residence time in the furnace section at 5.6 minutes. The 2,3,7,8-TCDD removal efficiency was found to range between 99.59 and 99.94 percent, depending on test run and analytical laboratory.

Residual concentrations of primary HO constituents, 2,4-D and 2,4,5-T, were below the detection limit value (DLV) requirement of 1 ppm for each of the treated soil samples analyzed. Based on use of the DLVs, the removal efficiencies for 2,4-D and 2,4,5-T were at least 99.992 and 99.997 percent, respectively. Evaluation of priority pollutant organics was not possible because none were detected in the feedstock samples in concentrations greater than 1 ppm. Inorganic concentrations in the treated soil were considered not hazardous, according to the U.S. Environmental Protection Agency (EPA) delisting criteria.

The 2,3,7,8-TCDD concentration in the treated scrubber solvent was reduced to less than 1 ppb in the one UV photolysis test performed. Removal efficiency for this isomer ranged from 99.90 percent (ITAS data) to 99.94 percent (Battelle data). Although the other congeners of PCDD and PCDF were reduced significantly, the analytical results showed that the treated solvent remained a hazardous waste as indicated by the following

sum of six congeners (tetra through hexa): 14-27 ppb (ITAS data) and 190-198 (Battelle data). Resolution of this problem could be accomplished by longer UV irradiation times, although residues (tars) from this process would still be handled as hazardous waste for offsite disposal.

Contaminated soil at JI could be treated by using a full-scale TD/UV photolysis process transported to and assembled in the field. Based on scale-up from the pilot-scale data, a cost estimate of \$11.5 million for treating of 20,000 tons (17,200 yd³) of 2,3,7,8-TCDD-contaminated soil has been prepared. The unit cost is about \$577/ton (\$671/yd³). This includes process, excavation, and utilities equipment shipping, a trial burn and data review by EPA, and soil excavation, soil pretreatment, TD/UV photolysis treatment, and return of treated soil to the excavated area. Estimated time to perform onsite installation, trial burn soil treatment, and site teardown is 35 weeks. Fourteen weeks are for the trial burn and standby period awaiting the data review. In addition, 5 weeks are provided for shipping each way by sea. Sensitivity analyses of seven variables (soil volume, shipping costs, diesel fuel prices, labor rates, equipment use changes, HO concentration, and feed rate) have been conducted to provide data for conditions other than those used in the reference case, with soil quantity found to be the most significant.

The costs for 20,000 tons remedial action at JI were estimated to be \$3.7 million more compared to the same action at an HO-contaminated site at the Naval Construction Battalion Center (NCBC) in Gulfport, Mississippi (Reference 1). Major factors were ocean shipping (\$1.5 million), equipment use charges related to shipping time (\$1.3 million), and more expensive energy (diesel fuel) for electricity and thermal desorber operation (\$0.3 million).

The thermal desorption process demonstrated the capability to treat dioxin-contaminated JI soil to meet Air Force test criteria, and may be considered for full-scale soil restoration of dioxin-furan contaminated coral-type soils. This demonstration, when added to the 1985 demonstration

at NCBC, shows the general soil treatment capability of the desorption process.

The UV photolysis process reduced the amount of dioxin constituent in the scrubber solvent. This reduction in dioxin from soil to solvent is important; however, the remaining scrubber solvent would require further treatment or disposal. Cost-effectiveness of treating the solvent to a nonhazardous condition was not evaluated. Other alternatives to this solvent treatment process should be considered before implementation.

Future use of the TD/UV photolysis technology will require compliance with applicable EPA regulations, and changes could affect its use for proposed remedial actions.

PREFACE

This report was prepared for the Air Force Engineering and Services Center, Engineering and Services Laboratory, Tyndall AFB, Florida, under Job Order Number (JON) 21039027. The principal contractor, EG&G Idaho, Inc., is a contractor for the Department of Energy, Idaho National Engineering Laboratory.

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This report is one of several reports encompassing the pilot-scale technology demonstrations on Herbicide Orange contaminated sites and is divided into four volumes. Volume I of this report summarizes the project approach, technology, operations, and results. Volumes II-IV contain Appendixes A through Y which cover official correspondence, results of analyses and cost estimates for full-scale system development and service at Johnston Island.

This technical report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS), Alexandria VA. At NTIS, it is available to the general public, including foreign nationals. This technical report has been reviewed and is approved for publication.



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SECTION I INTRODUCTION

A. OBJECTIVE

The objective of this program is to demonstrate the feasibility of using a thermal desorption/ultraviolet (TD/UV) photolysis process for soil cleanup and restoration of a Herbicide Orange (HO)-contaminated site at Johnston Island (JI), Pacific Ocean (Figures 1, 2). This program is sponsored by the Air Force Engineering and Services Center/Research and Development (AFESC/RD), Tyndall Air Force Base, Florida. The objective is twofold:

1. Perform a field demonstration with a pilot-scale unit at the JI location using the TD/UV photolysis process developed by the IT Corporation (ITC) of Knoxville, Tennessee.
2. Provide technical evaluation and cost estimates for full-scale cleanup/site restoration using the TD/UV photolysis process technology, which would provide information to compare this technology with others.

A specific goal of this technology testing was to reduce the total isomers of tetra-, penta-, and hexachlorodibenzo-p-dioxin and respective isomers of polychlorodibenzofuran to less than 1 part per billion (ppb). The overall soil treatment goal of the demonstration was to reduce the level of contaminants to criteria established by the U.S. Environmental Protection Agency (EPA) to facilitate delisting of the soil under the auspices of the Resource Conservation and Recovery Act (RCRA) of 1976, as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984.

The TD/UV photolysis process field demonstration was one of two technologies selected for the U.S. Air Force (USAF) Small-Scale Demonstration Program. The other technology was a thermal pyrolysis process by the J. M. Huber Corporation of Borger, Texas. The two

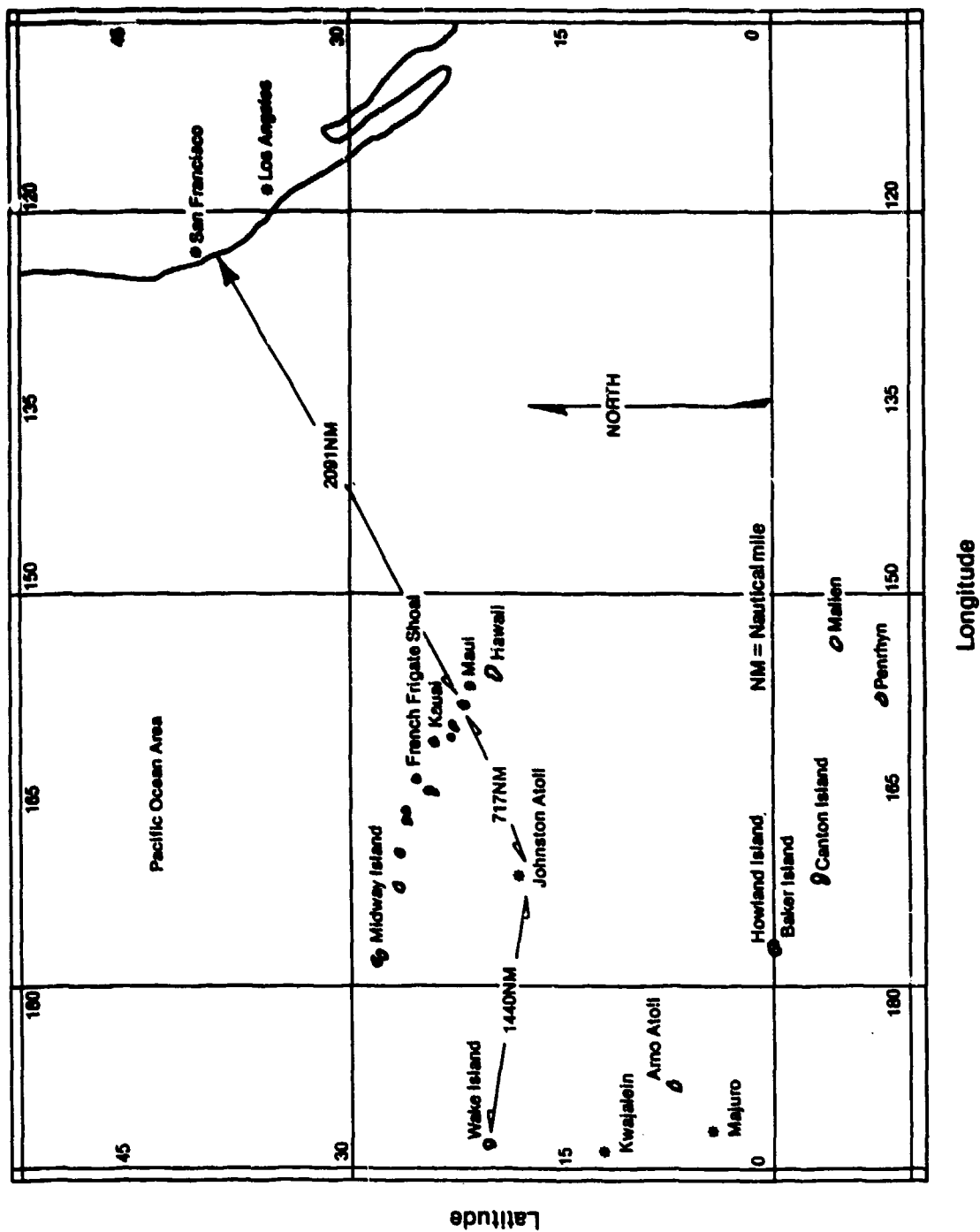


Figure 1. Location of Johnston Island.

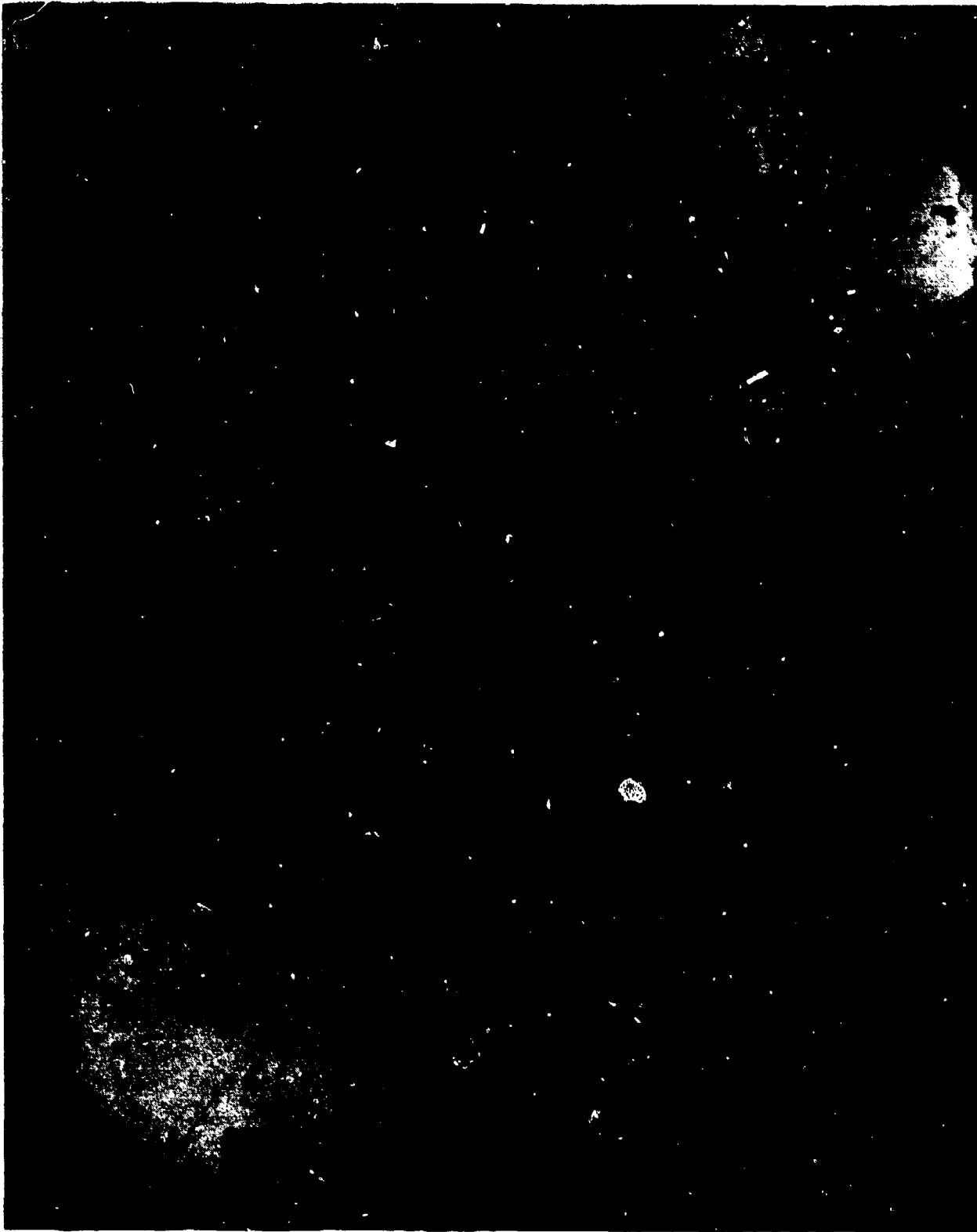


Figure 2. Aerial View of Johnston Island.

technologies were originally tested at the former HO storage site at the Naval Construction Battalion Center (NCBC) in Gulfport, Mississippi, in 1985. Results of these tests appear in separate reports (References 1 and 2).

The technologies were evaluated for decontamination treatment of former Department of Defense (DOD) HO sites. The purpose of the research demonstrations is to provide field data on the feasibility of the technology so that scaleup and cost-effectiveness can be determined for future restoration efforts.

The ITC process was selected for a second demonstration at JI to test the technology on a different soil type.

B. BACKGROUND

HO is primarily composed of two compounds, 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and various esters of these two compounds. It was sprayed as a defoliant in Vietnam during the 1960s and at Eglin Air Force Base, Florida, between 1962 and 1970 (References 3,4). Early in 1970, the herbicide 2,4,5-T was reported as a teratogen in mice and rats (Reference 5). More specifically, studies identified an unwanted byproduct, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), which is contained in 2,4,5-T, as the reason for the teratogenic effects (Reference 6). DOD discontinued the use of HO in 1970 (Reference 7). In 1972, the 1,370,000 gallons of HO located in South Vietnam were shipped to JI for storage (Reference 8). Figure 3 shows an aerial view of the drum stacks at the storage area before their removal. Another 850,000 gallons of HO were in storage at NCBC (Reference 8).

During the summer of 1977, the entire HO stockpile was disposed of at sea by high-temperature incineration (Project PACER HO). However, spills during the storage and handling of HO left the soil at the storage areas contaminated with dioxin. At JI, wood dunnage used to support the HO-contained drums during storage was found to be contaminated with HO



Figure 3. Pre-1977 Aerial View of JI H0 Site with Drums.

(Reference 9). A temporary incinerator was set up on JI at the former HO storage site to dispose of the dunnage, in addition to laboratory aprons, gloves, tissues, and a drum of solvents that had been used to clean glassware (Figure 4). The residual ash was disposed of at the JI site (Reference 9); a Johnston Island drawing indicates burial of the ash was in the northwest corner of the site (Figure 4).

The Air Force Logistics Command Plan and EPA permits for the disposal of HO committed the USAF to a followup storage site reclamation and environmental monitoring program. Immediately after the at-sea incineration, the USAF Occupational and Environmental Health Laboratory (USAF/OEHL) initiated site-monitoring studies of chemical residues at former HO storage sites (Reference 8).

1. Restoration Criteria

Of the polychlorodibenzo-p-dioxin (PCDD)/polychlorodibenzofuran (PCDF) isomers, the 2,3,7,8-TCDD isomer is considered most toxic to humans (Reference 10). This toxicity may be 10 times as toxic as the next isomer within this group (Reference 11). The Center for Disease Control (CDC) studied the risks of various concentrations of 2,3,7,8-TCDD in soil, and concluded that residual soil levels at or above 1 ppb of 2,3,7,8-TCDD in residential areas represent a level of concern (Reference 12). In certain commercial areas, higher levels in the soil may represent an acceptable risk to nonoccupationally exposed individuals. However, the CDC also concluded that, on ranges and pastures, lower soil levels in the soil may still be of concern since the 2,3,7,8-TCDD accumulates in the tissues of grazing cattle and rooting swine (Reference 12).

In a November 7, 1986, Federal Register notice (Reference 13), EPA proposed a standard for land disposal of PCDD/PCDF containing waste material. The proposed standard requires that these constituents (i.e., all isomers of tetra-, penta-, and hexachlorodibenzo-p-dioxins and dibenzofurans) be below a 1 ppb limit in the waste extract before being land-disposed. Further, wastes having concentrations that meet or exceed

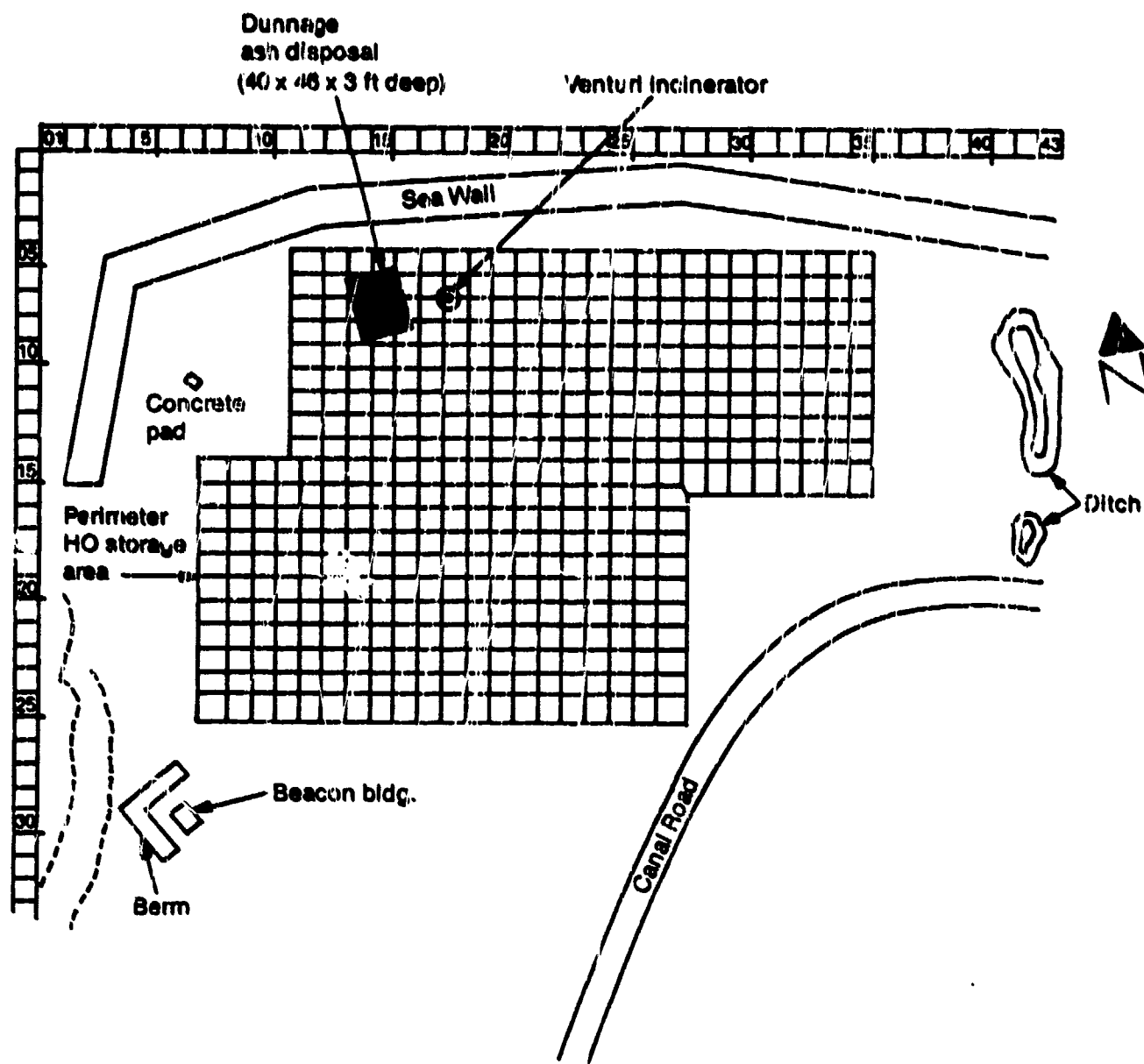


Figure 4. Locations of HO Dunnage Incinerator and Ash Disposal.

this limit may be treated in accordance with the criteria for incineration (40 CFR 264.343 and 265.352) and thermal treatment (40 CFR 383) for dioxins. Criteria that will be applied for full-scale restoration projects will depend on regulatory requirements in effect at the time and cost-effectiveness of the technologies being considered.

2. Storage Site Location

Johnston Island is part of a coral atoll that lies 717 nautical miles southwest of Honolulu (Figure 1). A possession of the United States, the atoll is controlled by the Field Command of the Defense Nuclear Agency. As such, the atoll is normally closed to the public.

JI is rectangular, about 2 miles long and 1/2 mile wide, and has an average elevation of 7 feet above sea level (Figures 2 and 5). Most of the island's coastline is artificial, consisting of stone and concrete facings built to form a low wall. In 1942, the island occupied 42 acres but was expanded to its present 625 acres, using local dredged materials. The island substrate generally consists of porous calcareous coral fill.

A 4.33-acre site on the west end of JI served as a storage area for 1,370,000 gallons (24,910 fifty-five-gallon drums) of H0 returned from South Vietnam (Figure 3). This location is on the downwind side of the island from prevailing trade winds. Figure 6 shows a ground-level view of the area after the drums were removed in 1977.

3. Previous Studies

Soil samples have been collected at the former storage area and analyzed during three periods: 1977-78, 1980-82, and 1985. The highest 2,3,7,8-TCDD level detected in the soil during the first two studies was 450 ppb (Reference 8). Three of 31 soil sampling locations exceeded 100 ppb. Six acres surrounding the storage area showed some contamination, but only 1 of 25 locations exceeded 1 ppb. Vertical soil profiles of 2,4-D, 2,4,5-T, and TCDD concentrations were determined by sampling the

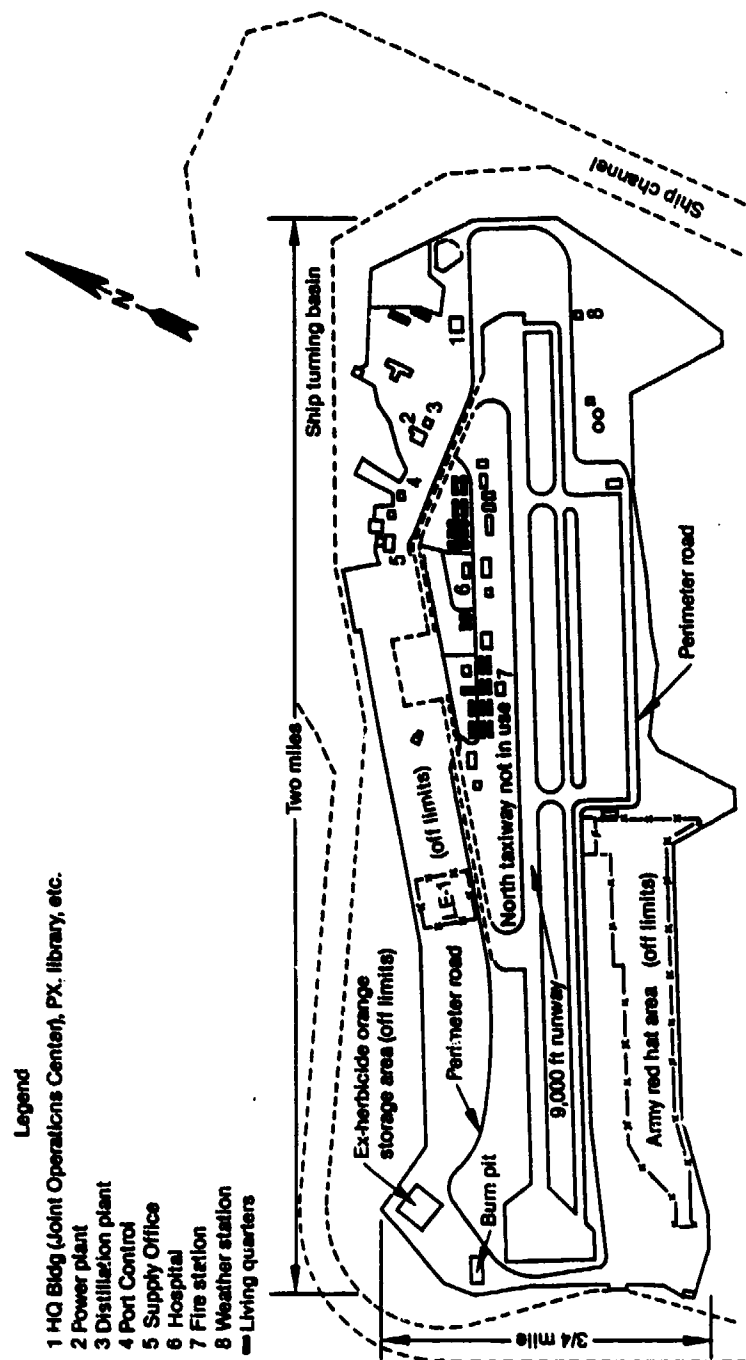


Figure 5. Map of Johnston Island.

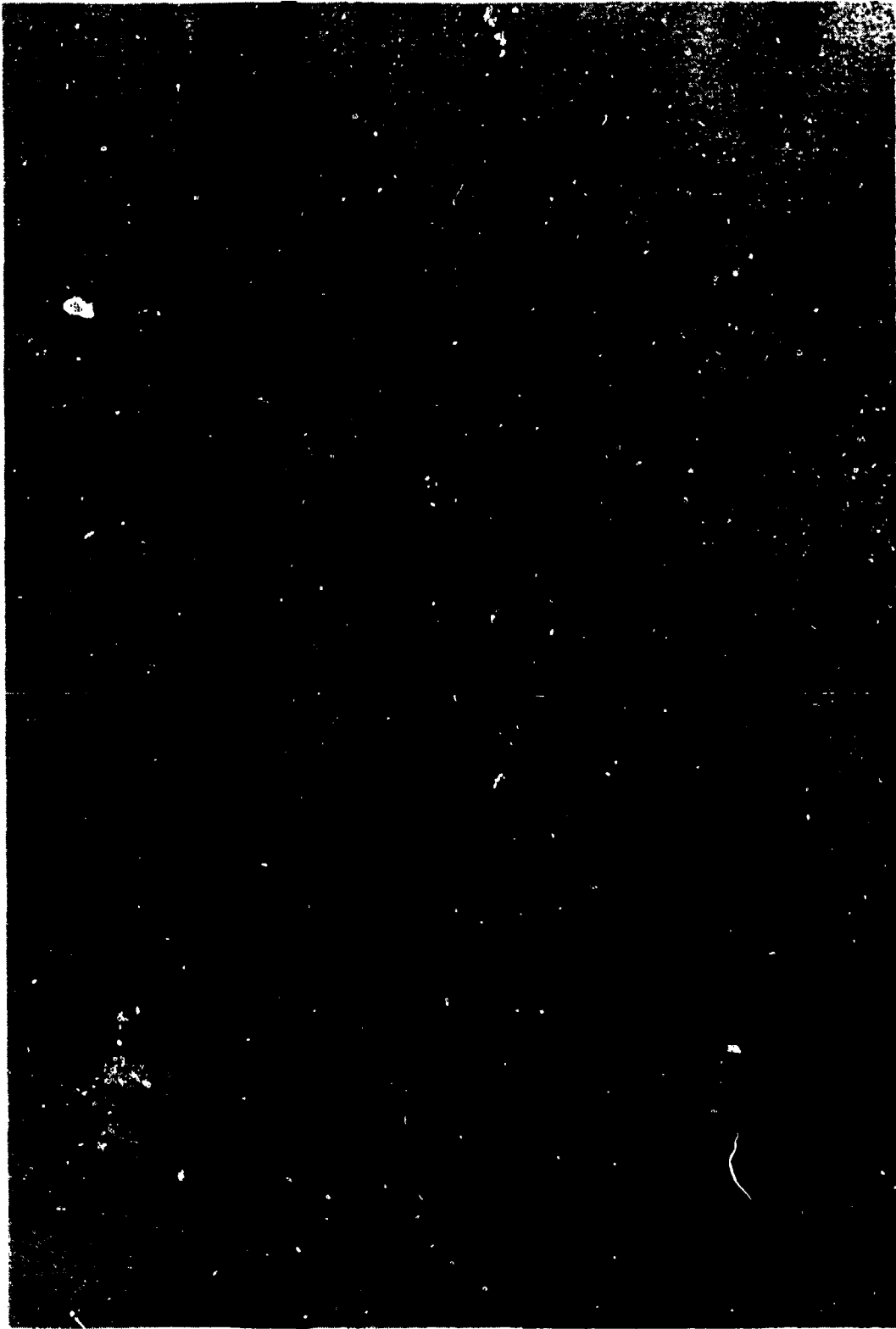


Figure 6. Ground View of JI H0 site (1983).

sidewall of excavated trenches. The maximum depth of penetration for detected 2,3,7,8-TCDD was 36 inches at one site where 0.035 ppb was detected.

In 1985, a detailed soil characterization of the JI storage site was conducted. The purpose of the study was to determine the horizontal and vertical extent of HO-derived 2,3,7,8-TCDD in addition to the vertical extent of herbicides 2,4-D and 2,4,5-T at former USAF storage sites (Reference 14).

Samples were collected and composited for 20- by 20-foot plots, both inside and outside the former fenced storage area at J1. A total of 545 plots were sampled. To determine the depth of penetration of TCDD into the coral soils, 33 locations were sampled to 12 inches in depth. At 15 locations, subsurface samples were collected to a depth of 5 feet. The vertical distribution of the herbicides 2,4-D and 2,4,5-T was also investigated by analyzing all subsurface samples for these compounds.

Of the 15 deep subsurface sample locations, one sample location (0814) lies within the dunnage ash burial area shown in Figure 4; another sample location (0613) lies next to this area. These locations showed higher subsurface 2,3,7,8-TCDD concentrations compared to the samples for the other 13 plots investigated (Reference 14) and tend to confirm the general area of the ash burial site.

The validated data indicate that 2,3,7,8-TCDD contamination of the former fenced storage area is highly variable and random. TCDD concentrations ranged from less than a detection limit of 0.01 ppb to 163 ppb. The arithmetic mean for all plots inside the fenced area was 8.6 ppb.

The statistical analysis of the uncertainty associated with the sampling program indicates that about 17,600 yd³ of soil (entire 4.33 acres of site to a depth of about 30 inches) would require removal, assuming a cleanup criteria of 1 ppb at a 95 percent confidence level.

With more detailed subsurface sampling, the soil requiring treatment could reduce to a volume as low as 9,800 yd³.

4. Regulatory Authorizations and Public Participation

Because of major changes in governing regulations, this demonstration suffered major impacts in scope, schedule, and budget. The previous two technology demonstrations at NCBC were governed by regulations promulgated under the Toxic Substances Control Act (TSCA), under the authority of EPA's Dioxin Disposal Advisory Group. In 1985, management of dioxins was transferred from TSCA to authority under RCRA of 1976, as amended by HSWA of 1984.

HSWA gave EPA the authority to issue research, development, and demonstration (RD&D) permits, without promulgation of permitting regulations that would establish standards for technologies or processes that treat hazardous waste in an innovative and experimental manner. As codified in 40 CFR Part 270.65, these RD&D permits were to help develop safe alternatives for land disposal of hazardous waste, a primary goal of the amendments, by expediting the permitting process to demonstrate the technical and/or economic feasibility of experimental and innovative technologies and processes. In addition, permitting authority was given to regional EPA offices, as well as the authority to modify or waive the permitting and technical requirements applicable to other types of hazardous waste management facilities.

Therefore, this demonstration fell under the jurisdiction of EPA, Region IX, San Francisco, California, and the RCRA system. An RD&D permit application was submitted to Region IX on May 9, 1985 (Appendix A, Exhibit 1). Verbal comments were obtained from EPA, and the application was revised and resubmitted September 13, 1985 (Appendix A, Exhibit 2). Comments were obtained from EPA on the resubmittal, and the application was revised and resubmitted February 5, 1986 (Appendix A, Exhibit 3). Additional comments were obtained from EPA, and the application was again revised and resubmitted on March 3, 1986 (Appendix A, Exhibit 4).

Because the project fell under RCRA, it was also necessary to submit a notification of hazardous waste activity to obtain a generator identification number. This was done on August 15, 1985 (Appendix B, Exhibit 1). Additionally, in January 1985, EPA published regulations specifying that dioxin-contaminated soil that had been thermally treated to remove dioxin would still be considered a hazardous waste. As a result, the treated soil had to be managed as a hazardous waste. Because no hazardous waste disposal facilities were accepting dioxin wastes, it became necessary to define an interim storage facility at JI and submit an application for a permit from EPA; this was done on October 23, 1985 (Appendix B, Exhibit 2). Following comments from EPA, a reapplication for the permit was made on January 30, 1986 (Appendix B, Exhibit 3).

Formal public notification of intent to issue a permit and a public hearing and comment period for the draft RD&D permit were publicized in two Honolulu newspapers (Honolulu Star Bulletin and Honolulu Advertiser) as Public Notice TT0570090004 (Appendix C) and as radio spots on local stations beginning March 30, 1986.

The administrative record, which included the RD&D permit application, draft permit, and fact sheet assembled by EPA, was made available for public inspection at the Region IX Headquarters. The draft permit and fact sheet were also available for public inspection at the Honolulu EPA Office and four public libraries.

EPA Region IX conducted the public hearing on April 29, 1986, at 7 p.m. at the Liliha Library in Honolulu. Representatives from AFESC, the USAF Surgeon General's Office, EG&G Idaho, ITC, Department of Energy-Idaho Operations Office, Defense Nuclear Agency, and Hawaii EPA attended.

In general, concerns and comments registered by members of the public were not aimed directly at the technology demonstration, but concern was expressed regarding hazardous waste management activities of U.S. government agencies as a whole. EPA received no negative comments about the technology demonstration during the public comment period.

The public comment period ended on May 14, 1986. Region IX transmitted the final RD&D permit to AFESC May 22, 1986 (see Volume IV). AFESC did not receive notification from Region IX of any generator identification number for the waste generation activity. Rather than authorize a separate permit for the interim storage of the treated soil and other hazardous wastes resulting from the testing, this authority was included within the RD&D permit (Volume IV). Permit conditions specified that wastes produced by the experiment procedures be treated as hazardous waste and stored at JI. Further, the waste inventory allowed by the permit could not exceed a total of 20 drums of soil (Waste No. F028) and solvent (Waste No. F027), and 150 drums of aqueous cleaning residues and solid waste such as contaminated clothing (Waste No. F027). Actual waste quantities resulting from the test program are presented in Section IV.D.6.

The JI permitting process under the auspices of RCRA within Region IX was more difficult and time-consuming (12.5 months) compared to the NCBC permitting process under the auspices of TSCA within Headquarters, EPA (3.5 months). Both factors increased the cost significantly. Part of the difficulty was attributed to a difference in regulatory environment and regional interpretation of responsibilities. Information and further discussion on the difficulties and costs are presented separately (Reference 15).

C. SCOPE/APPROACH

The scope of this report is to document the results of a pilot-scale TD/UV photolysis process to treat JI soil contaminated by polychloro-dibenzo-p-dioxins and polychlorodibenzofurans and to present a cost estimate for full-scale remedial action by this process.

The approach for the field demonstration objective was to use the ITC pilot-scale unit at the JI site. A suitable quantity of contaminated soil (about 2400 pounds) was excavated, analyzed, and prepared to meet the necessary feedstock requirements for the thermal desorption tests. The TD and UV photolysis processes were operated at variable conditions to

demonstrate feasibility under field conditions and ascertain optimum operating parameters. Sampling activities were performed by Ecology and Environment, Inc. (Buffalo, New York, and Kansas City, Kansas). Laboratory analyses were performed by IT Analytical Services, Knoxville, Tennessee, and Battelle Columbus Laboratories, Columbus, Ohio. Field support was obtained from Holmes and Narver (Johnston Island and Oakland, California) and ITC's West Coast Field Office in Martinez, California. EG&G Idaho provided overall project management and performed verification and validation of analytical data. An AFESC representative provided liaison with involved federal agencies.

The approach for the full-scale remedial action cost estimate associated with the technology process was to use cost information from the TD/UV photolysis technology estimates for the restoration at the NCBC HO site at Gulfport, Mississippi, to the extent applicable (Reference 1). New estimates for shipping and unique JI activities were determined by an estimating group at EG&G Idaho.

SECTION II

TEST TECHNOLOGY

A. TECHNOLOGY DESCRIPTION

The technology to decontaminate soil by using the thermal desorption/ultraviolet (TD/UV) photolysis process is based on:

(1) separating, by volatilization, organic contaminants, such as 2,4-D, 2,4,5-T, and 2,3,7,8-TCDD, from a natural soil matrix; (2) collecting the desorbed organic contaminants in a suitable solvent; and (3) treating the contaminant-laden solvent using UV photolysis. The overall process may be operated in either a continuous or a batch mode. The TD and UV photolysis unit operations may be operated simultaneously or separately. For a large remedial activity, as an example, unit operations would be continuous and simultaneous for economy. Figure 7 is a block flow schematic of the complete process.

Soil, after preparation and sampling, is continuously fed to an indirectly heated desorber unit, operating in a temperature range of 850 to 1100 °F. Soil preparation depends on the type of desorber equipment used and the condition of the specific soil. Generally, some size control such as a coarse screening operation is necessary. After sufficient residence time in the desorber at the proper operating temperature, the treated soil is discharged. Required soil temperatures and residence times will depend on the volatility of the contaminants. For compounds with extremely low volatility, such as 2,3,7,8-TCDD, a residence time of about 10 minutes at a soil temperature of 1000 °F would be expected to achieve 99 percent removal of the initial dioxin. A higher soil temperature reduces the residence time. Desorption temperatures are significantly lower than incineration temperatures because thermal destruction of the contaminants by combustion or pyrolysis is not required.

The volatilized organics and moisture contained in the soil are continuously swept out of the desorber by a gas purge. An inert gas (nitrogen) is used to avoid the potential for a combustible mixture in the

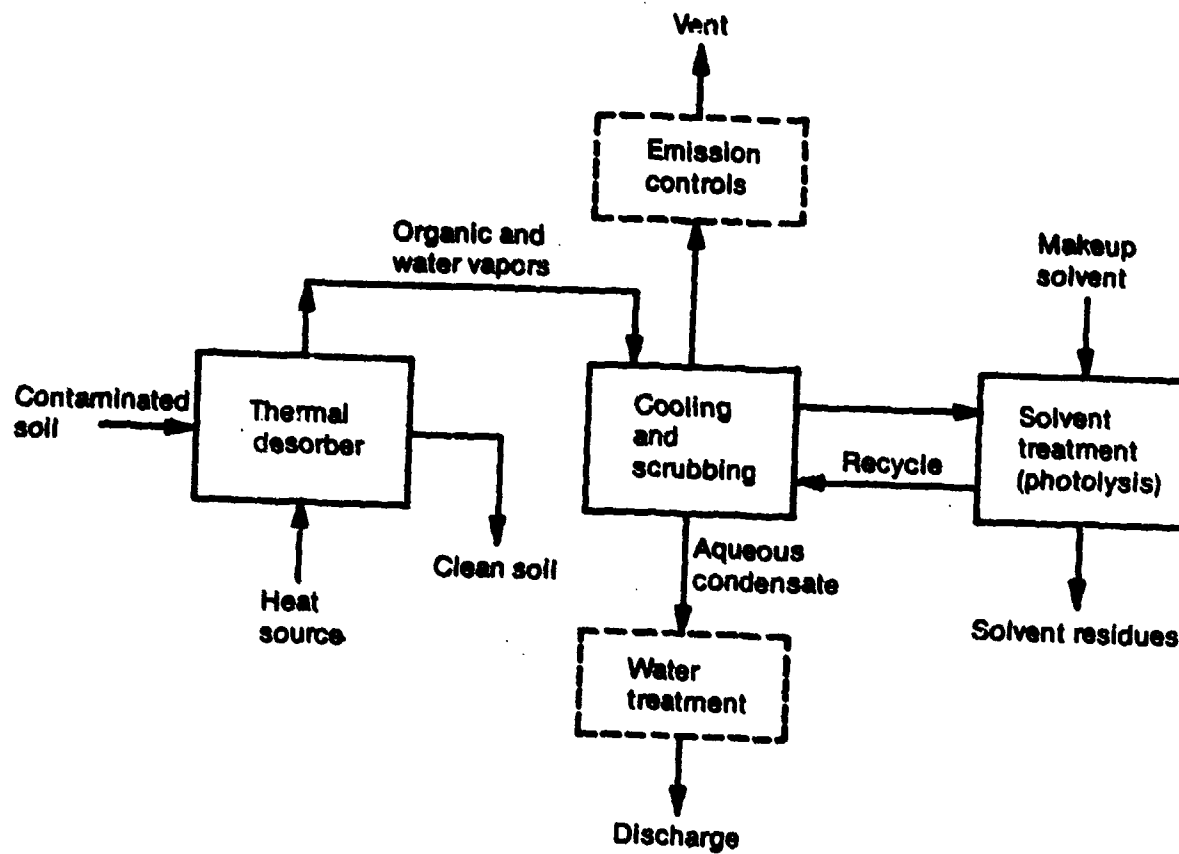


Figure 7. Thermal Desorption/UV Photolysis Process Concept.

desorber because a hydrocarbon solvent is used downstream to scrub the off-gas. A high-boiling hydrocarbon solvent cools and scrubs the off-gas, and the "clean" nitrogen stream is recirculated to the desorber. To allow for any influx of air that is contained in the soil feed or through leakage at the soil inlet/discharge and desorber seals, nitrogen makeup is introduced to the recirculating gas stream, based on monitoring of the oxygen level. Gas displaced from the recirculation loop as a result of air influx is treated by a particulate filter and activated charcoal adsorbers before venting to ensure that desorbed contaminants or other organic compounds originating from the solvent are not emitted.

The solvent from the scrubber is collected in a receiver that serves as a decanter to separate condensed water from the solvent and to allow solid particles to settle out. The solvent is recirculated to the scrubber through a heat exchanger to remove the heat absorbed from the off-gas. The entire solvent circulation loop is maintained at a relatively low temperature (<100 °F) to reduce the vapor pressure of the solvent and the absorbed organic contaminants and to minimize the amount of organics remaining in the gas exiting the scrubber. The water from the receiver/decanter is withdrawn as it accumulates and is treated, as necessary, to allow discharge. Treatment would typically consist of filtration and carbon adsorption to remove soluble toxic organic contaminants.

The solvent containing the contaminants 2,4-D, 2,4,5-T, 2,3,7,8-TCDD, and other scrubbed organics is treated in a UV photolysis reactor. Photolytic reactions convert these chlorinated contaminants to products that facilitate disposal. The solvent is recycled to the scrubber, with makeup solvent added as necessary. The relative quantity of the solvent purge from the scrubber to the photolysis reactor depends on the concentration of contaminants in the soil, the solubility of these contaminants in the scrubbing solution, and the photolysis reaction rate. Another consideration in determining the proper maximum concentration of contaminants to be controlled in the solvent is the volatility of the contaminants and associated emissions to the vent gas emissions control

unit. At the conclusion of a run, the solvent is treated by recirculating it through the photolysis reactor until the concentrations of 2,3,7,8-TCDD and other HO constituents are reduced to within acceptable limits.

Depending on constituents remaining, the residual solvent may require disposal as a hazardous liquid waste (FO27) for which there are no current RCRA-permitted disposal facilities (see Section V.B for the photolyzed solvent at JI).

B. PREVIOUS TECHNOLOGY PERFORMANCE

The thermal desorption/UV photolysis process developed by ITC had not been used before the pilot-scale testing at NCBC and JI. ITC developed basic information on the expected treatment performance during a laboratory verification testing phase of this project. These bench-scale test data were used to finalize the design and operating specifications for the pilot-scale system and to provide technical information to support the approval process for the regulatory permits. The results of the laboratory verification testing are summarized below (see also Volume III of Reference 1). The various bench-scale experiments and associated analytical work were performed at ITC's Environmental Research Laboratory in Knoxville, Tennessee, during early 1985, just before NCBC pilot-scale testing.

1. Thermal Desorption Testing

ITC determined the effect of residence time and temperature on the desorption of 2,3,7,8-TCDD on samples of HO-contaminated soils from NCBC, Johnston Island, and Eglin AFB as part of a joint project for EPA's Municipal Environmental Research Laboratory in Edison, New Jersey, and for the AFESC. This study was done to determine the applicability of the EPA's mobile incineration system for treating soil contaminated with HO. This work was an extension of similar treatability testing performed for EPA on two soil samples from dioxin-contaminated sites in Missouri. The report of the NCBC, JI, and Eglin HO-contaminated soil tests is attached to the NCBC

technology demonstration report as Volume III. The reports describing the Missouri dioxin-contaminated soil test have been submitted to EPA (Reference 16).

These laboratory treatability studies demonstrated that 2,3,7,8-TCDD could be reduced from over 100 ppb to less than 1 ppb at desorption temperatures as low as 1050 °F. A statistical evaluation of time-temperature data for the five soils indicated a reasonable correlation between the logarithm of the removal efficiency and the product of 2,3,7,8-TCDD vapor pressure and residence time. The relationship between soil temperature and the required residence time to achieve organic removal follows an inverse exponential. The shapes of the curves in Figure 8 are based on more extensive data obtained using the same experimental technique on the two Missouri soil samples studied for EPA (Reference 1); the initial time period (before "time zero") corresponds to the sample heatup time. These results were done with static, air-dried soil of controlled particle size (less than 0.1 inch). Particle size in these studies was shown to have an effect for gross differences only (e.g., 2-inch cubes versus 0.1-inch material, see Volume III of Reference 1). Prediction of treatment performance in larger-scale equipment under typical field conditions must consider the potential influence of heat and mass transfer factors.

The desorption tests of NCBC and JI soils also demonstrated that other HO constituents, including trace levels of other PCDDs and PCDFs, were effectively removed at treatment conditions adequate for 2,3,7,8-TCDD removal to 1 ppb. Removal efficiencies for 2,4-D and 2,4,5-T were greater than 99.99 percent. The results of these laboratory tests provided the basis for selecting pilot-scale equipment and projecting operational conditioning to process these soils.

2. Photolysis Testing

ITC developed a treatment process for dioxin-contaminated wastes that included extraction of the dioxin in hexane followed by UV photolysis

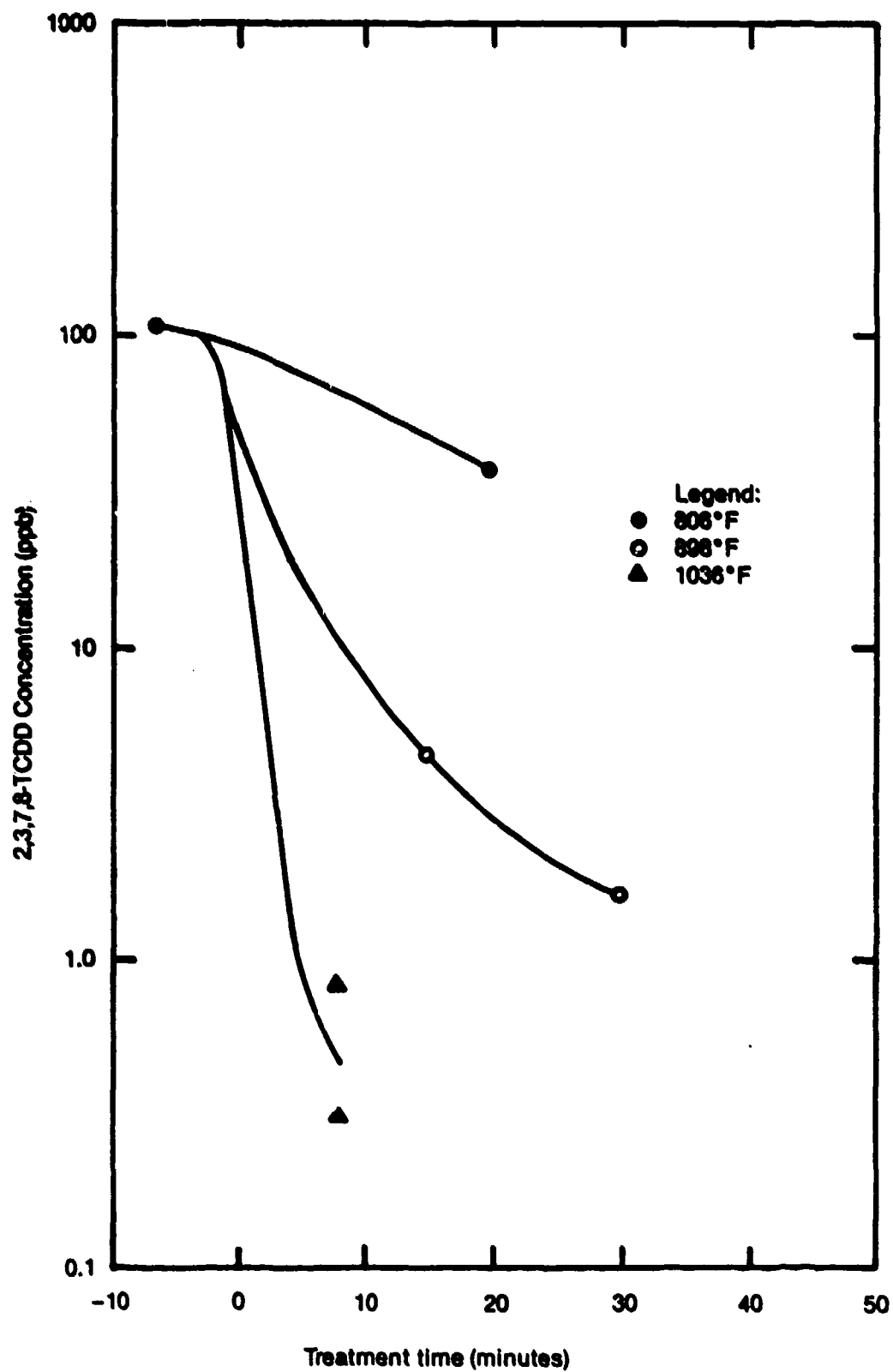


Figure 8. Effect of Time and Temperature on Removal of 2,3,7,8-TCDD from JI Soil.

as part of a waste treatment project for the Syntex (USA), Inc., plant located in Verona, Missouri (Reference 17). After extensive laboratory testing, this process was successfully scaled up and operated to reduce the concentration of 2,3,7,8-TCDD in waste tars from above 300 ppm to less than 0.5 ppm. The laboratory test data showed that the reaction could be continued to achieve 10 ppb residual 2,3,7,8-TCDD levels. Other studies reported in the literature have also shown the effectiveness of UV photolysis in treating dioxins and other chlorinated aromatic compounds (References 18-23).

ITC conducted bench-scale photolysis tests during the laboratory confirmation phase of the NCBC pilot-scale project. In addition to verifying that 2,3,7,8-TCDD could be effectively treated (to a goal of 1 ppb or less) in the specific solvent matrix representing the desorber scrubber composition, this testing established reaction kinetics that were used to develop design and operating parameters for the pilot-scale system. This testing also investigated potential difficulties that could develop in a photolysis system. The following paragraphs present an overview of the results.

The photolysis tests were performed with both simulated scrubber solutions (solvent "spiked" with target HO compounds) and actual scrubber solutions generated by using a bench-scale desorption/scrubbing apparatus. The solvent selected for the bench-scale and pilot-scale testing at NCBC and JI was a high-boiling-point isoparaffin blend trademarked Soltrol[®] 170. Properties of this solvent are given in Appendix D. Initially, simulated scrubber solutions were prepared from samples of the specific butyl esters of 2,4-D and 2,4,5-T obtained from a previous HO manufacturer. Also, the corresponding free acids were used for certain tests, since it was probable that hydrolysis of the esters in the environment could result in both ester and acid forms being present in the soil to be treated. A separate simulated scrubber solution was prepared by adding only 2,3,7,8-TCDD.

Actual scrubber solutions were produced using a bench-scale system consisting of a tube furnace and several impingers. Samples (approximately 100 grams) of contaminated soil from NCBC and JI were placed in a 1-inch quartz tube, inserted into a furnace, and exposed to the temperatures and times necessary to achieve complete desorption (see Volume III of Reference 1). The desorbed HO constituents were collected in the impingers, which contained Soltrol[®] 170 solvent. After the tube furnace had been cooled, a portion of the 200 to 400 mL of combined scrubbing solution was subjected to photolysis testing.

The photolysis experiments were conducted in two different 500 mL batch reactors. One reactor used a magnetic stirrer to promote mixing of the solution during photolysis, and the other used a recirculation pump to promote flow through the reactor. Either a 100-watt or a 450-watt UV high-pressure quartz mercury vapor lamp was used for different experiments. The spectral energy distribution of the mercury lines for each lamp is shown in Table 1.

Figure 9 illustrates the rate of disappearance of 2,3,7,8-TCDD for both a prepared (spiked) Soltrol[®] solution and an actual scrubber solution using a 100-watt lamp. The significant difference in reaction kinetics is probably a result of competition for UV light or reduction in light transmissivity caused by the other HO constituents or their reaction products in the actual scrubber solution; these constituents are present at four or five orders of magnitude higher concentration than 2,3,7,8-TCDD. Using a 450 watt lamp in the stirred reactor system resulted in a reduction of 2,3,7,8-TCDD concentrations from 200 ppb to nondetectable levels in 5 minutes of exposure.

Tests in the stirred reactor using Soltrol[®] 170 spiked with the free acids and butyl esters of 2,4-D and 2,4,5-T verified that photolysis effectively reduced the concentration of these compounds from approximately 1000 ppm levels to <10 ppm levels within 30 to 60 minutes reaction time when using a 100 watt lamp. Tests using actual scrubber solutions were modified to account for low or nondetectable concentrations of the esters

TABLE 1. SPECTRAL ENERGY DISTRIBUTION FOR MERCURY-VAPOR LAMPS IN UV PHOTOLYSIS TESTS

Mercury Lines (Angstroms)	Lamp Radiated Energy ^a		
	Bench-Scale Tests		Pilot-Scale Test
	100 W	450 W	1200 W
13673 (infrared)	0.65	2.6	10.15
11287	0.62	3.3	6.93
10140	0.85	10.5	31.60
5740 (yellow)	1.55	20.0	69.35
5461 (green)	1.35	24.5	40.52
4358 (blue)	1.08	20.2	53.00
4045 (violet)	0.75	11.0	24.20
3660 (UV)	1.40	25.6	97.10
3341	0.13	2.4	6.93
3130	1.02	13.2	50.6
3025	0.41	7.2	32.9
2967	0.32	4.3	15.2
2894	0.10	1.6	4.41
2804	0.12	2.4	13.9
2753	0.06	0.7	4.2
2700	0.07	1.0	4.85
2652	0.30	4.0	27.80
2751	0.11	1.5	6.30
2537 (reversed) ^b	0.34	5.8	24.1
2482	0.10	2.3	10.15
2400	0.05	1.9	7.30
2380	0.03	2.3	8.40
2360	0.02	2.3	6.20
2320	0.02	1.5	7.65
2224	0.04	3.7	9.20
Total	11.49	175.8	572.9

a. Radiated mercury lines in high-pressure quartz mercury vapor lamps supplied by Conrad-Hanover, Inc., Newark, New York.

b. 2537 line is reversed in high-pressure lamps.

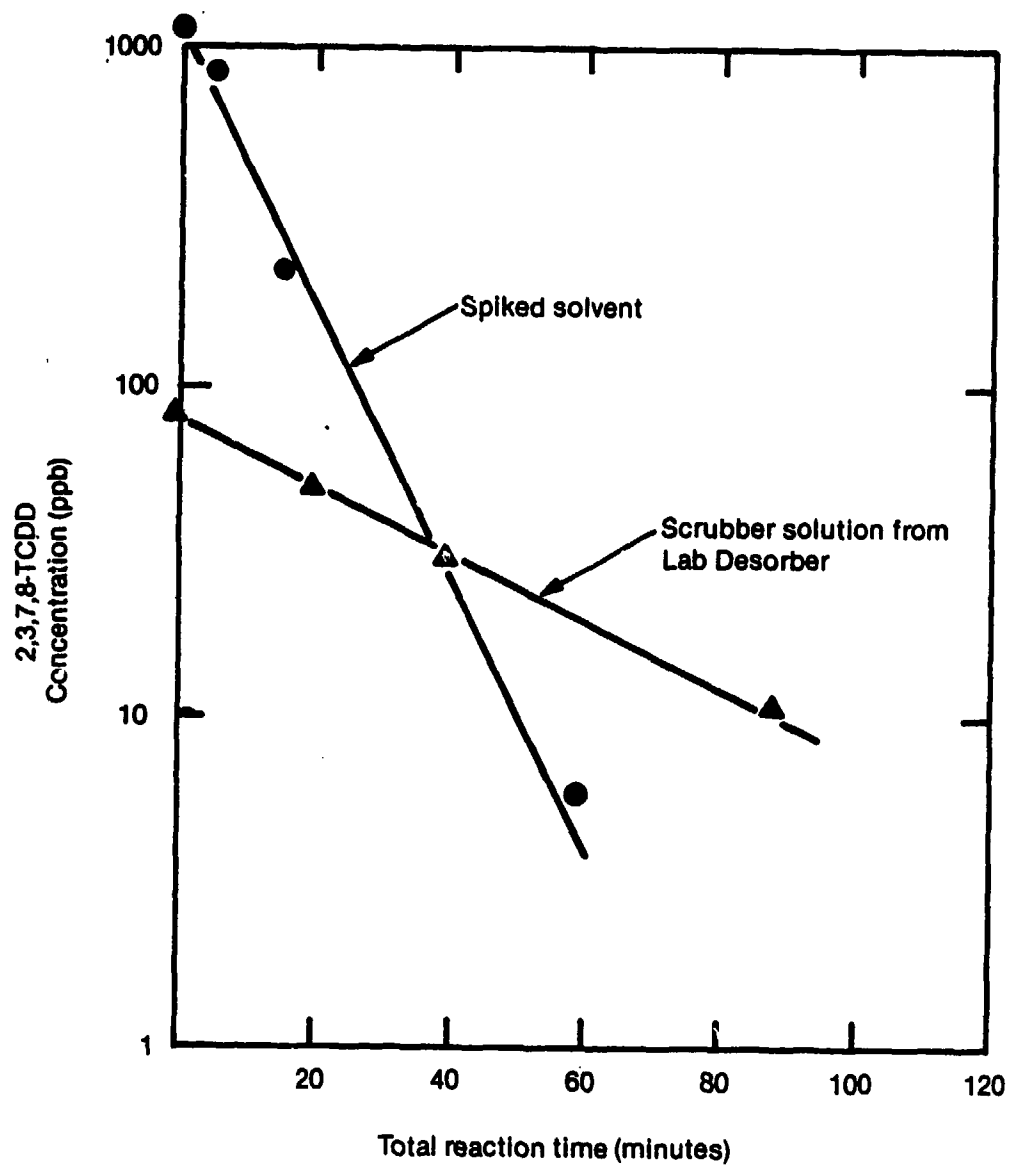


Figure 9. Photolysis Reaction Kinetics of 2,3,7,8-TCDD.

and free acids found in the samples of scrubber solutions. After investigating potential difficulties with the analytical methodologies caused by the characteristics of the Soltrol[®] matrix, it was determined that these HO constituents had been converted to the corresponding chlorophenols, apparently by partial thermal decomposition during desorption. Therefore, the kinetics of 2,4,5-trichlorophenol photolysis was measured with an actual scrubber solution from a desorption of NCBC soil. This test, using the recirculated reactor system with a 450-watt lamp, showed 99 percent removal in 40 minutes reaction time.

In summary, the laboratory photolysis experiments demonstrated that 2,3,7,8-TCDD and the primary HO constituents expected to be present in the desorber off-gas scrubber solution could decompose photochemically and that achieving 1 ppb residual 2,3,7,8-TCDD was feasible. However, it was also determined that solvent discoloration and generation of high molecular weight materials (composition unknown) tend to coat the reactor and lamp well surface and pose potential process problems that required further investigation during the pilot-scale demonstrations. Conversion of chlorinated phenolics to phenolic polymers (tars) has been observed in previous UV irradiation testing (References 17 and 22). These results were used in selecting the appropriate type of pilot-scale photolysis reactor and designing the overall photolysis system to be compatible with the planned desorption pilot tests.

C. PILOT-SCALE HARDWARE DESCRIPTION

For the pilot-scale testing at JI, the three major steps of the process-feed preparation, thermal desorption with off-gas scrubbing, and UV photolysis were carried out independently, as done at NCBC. This facilitated testing while providing adequate data for scale-up and performance evaluation. The details of the pilot-scale process hardware are described in this section. Modifications made specifically for the JI testing are discussed at the end of this section. Figures 10 and 11 are simplified schematics of the process flows for the thermal desorber/off-gas treatment unit and the UV photolysis unit, respectively.

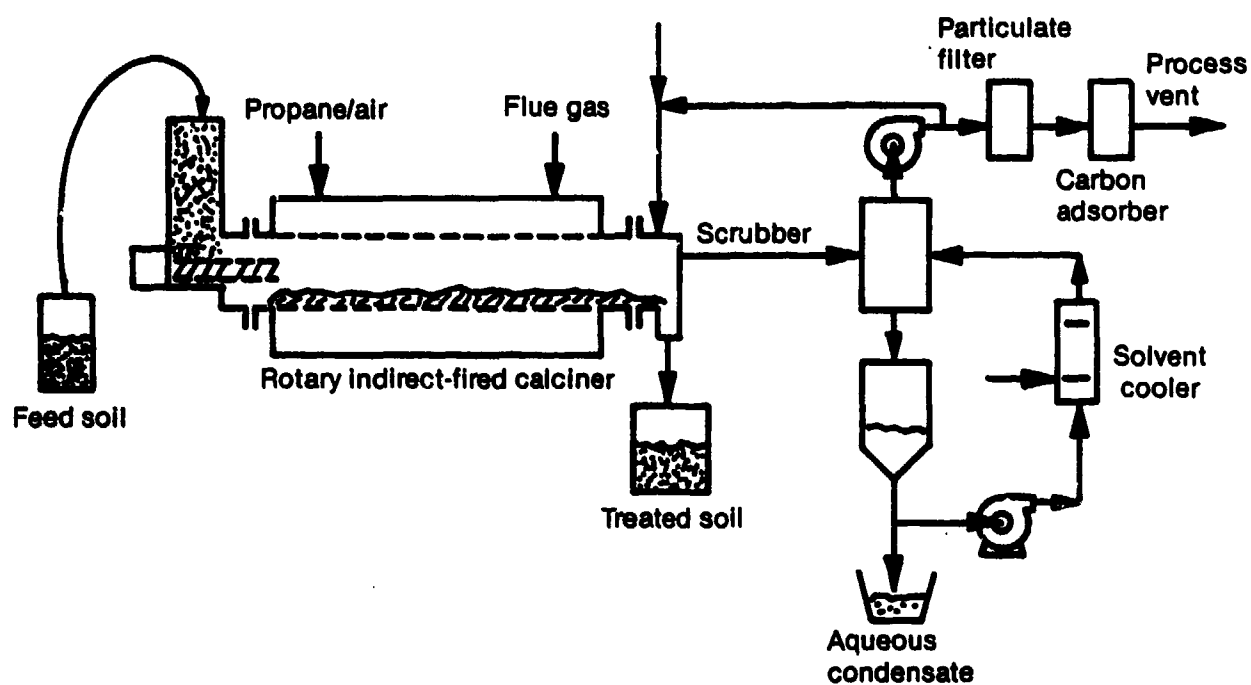


Figure 10. Thermal Desorber/Off-Gas Treatment Pilot-Scale Unit Schematic.

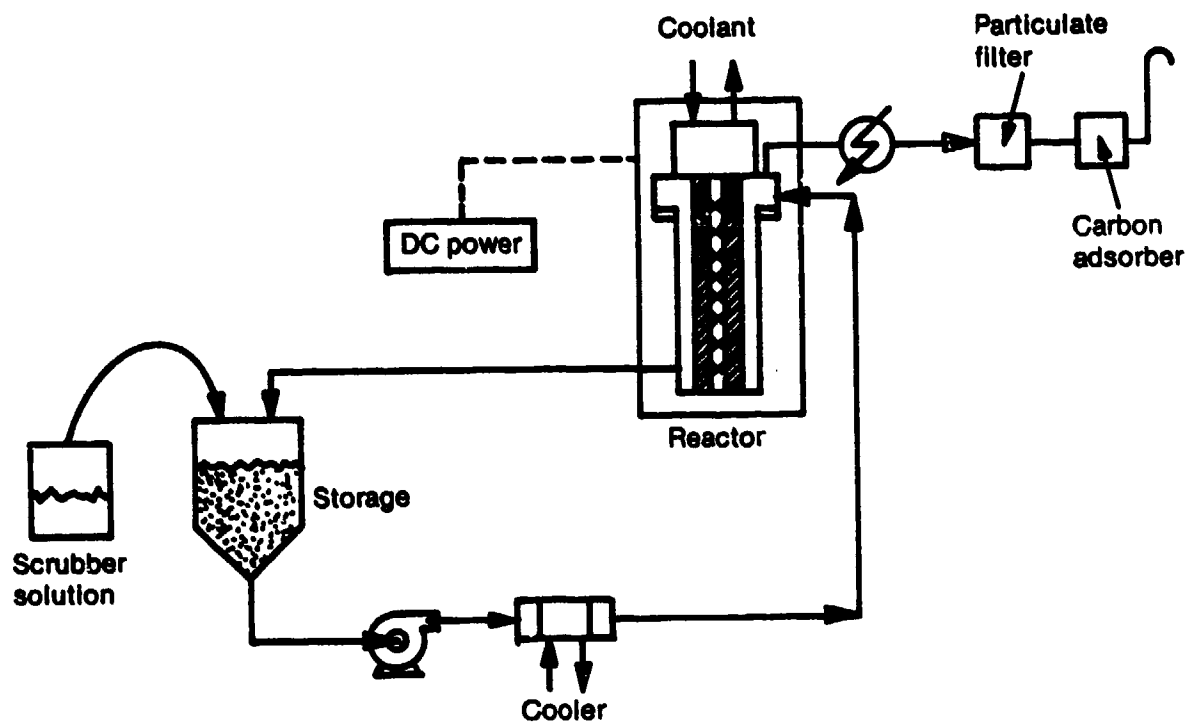


Figure 11. UV Photolysis Pilot System Schematic.

1. Feed Preparation Unit

A small 2-horsepower reciprocating jaw crusher was used to reduce the maximum size of the soil feed to approximately 1/2 inch to meet mechanical clearances in the desorber feedscrew conveyor. The crusher can accept soil or rocks up to 2 3/8 inches by 4 inches and is adjustable to produce the desired product size. To provide a soil feed that would flow properly into the crusher and desorber feed units, the soil was dried in a large metal tray covered partially with clear plastic to form a solar-heated and well-ventilated enclosure. Further discussion about the feedstock is presented in Section IV.B.

2. Thermal Desorber Unit

The thermal desorber unit consists of a feed hopper and a desorber (Figure 12). A hopper having sufficient capacity (approximately 100 pounds) for 2 to 3 hours of operation is manually loaded. A gasketed lid is placed on top of the hopper to prevent air infiltration; a slide-gate valve at the bottom of the hopper enables the hopper to be loaded during desorber operation without air infiltration. A sight glass in the hopper enables monitoring of the level and insurance of proper flow. The screw conveyor beneath the hopper is integral with the rotary desorber. It is constructed of Type 316 stainless steel and has a 2-inch-diameter screw driven by a variable-speed gear reducer unit. Flows of 0.3 through 3 ft³/hr (approximately 25 to 250 lb/hr, assuming a density of 85 lb/ft³) are possible. The conveyor screw discharges beyond the feed end of the rotating desorber chamber to ensure soil is properly forwarded toward the desorber discharge.

The desorber consists of a continuously rotating tube (chamber), partially enclosed within a gas-fired shell (furnace), manufactured by C. E. Raymond, Inc. The inner chamber is 6 1/2 inches internal diameter and 14 feet, 0-7/8 inch long, with 6 feet, 8 inches of this length within the furnace zone. Baffles are placed at intervals within this tube to provide increased mixing of the soil. A stationary pipe extends from the

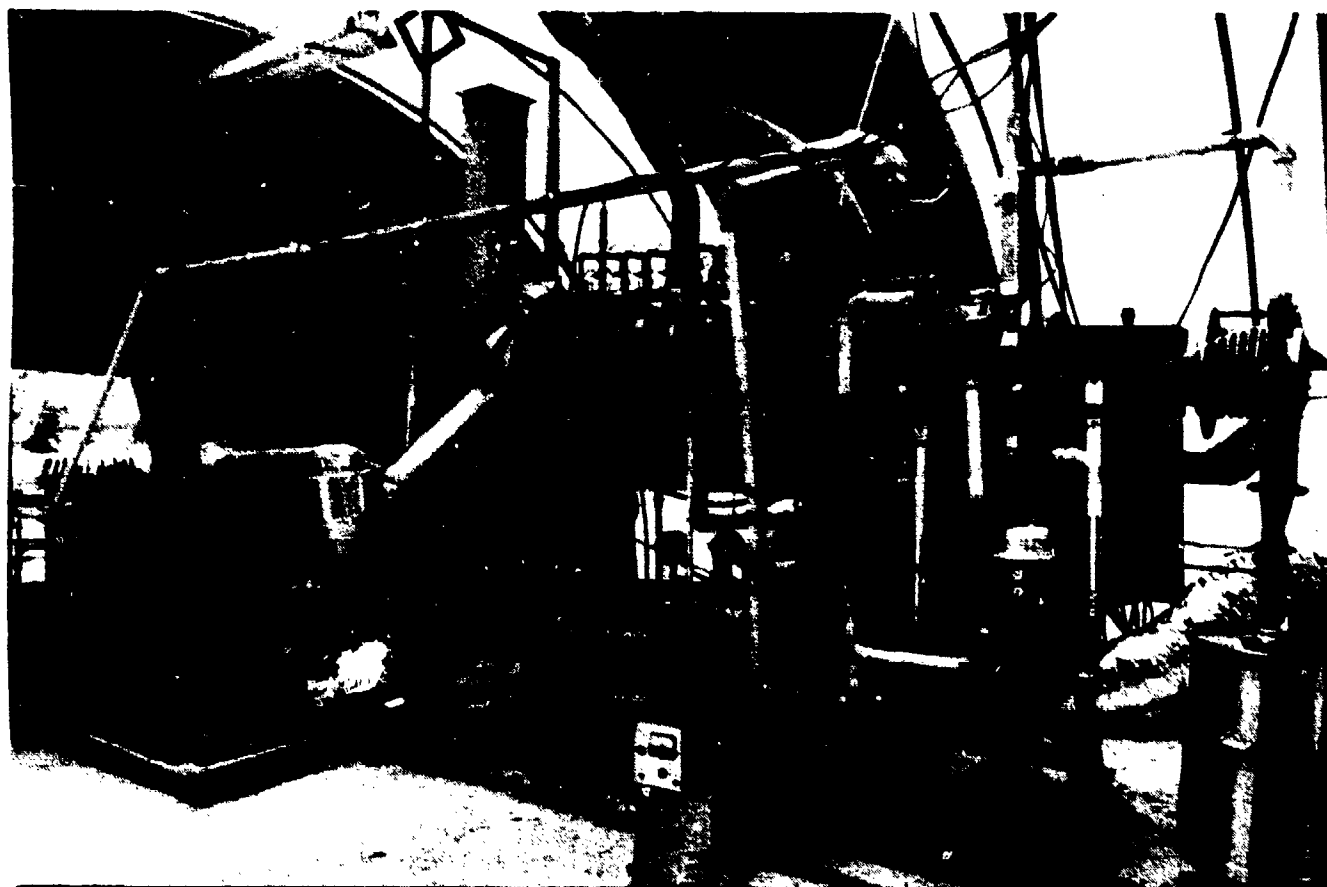


Figure 12. Close of Thermal Desorber and Scrubbing Unit.

discharge end into the chamber, serving as a thermowell for six thermocouples to monitor the temperature of both solids and gas along the tube length. The chamber can be rotated at speeds from 1.16 to 11.6 rpm. The entire desorber unit can be inclined to further adjust the flow rate of solids. Typically, a slope of 2 to 3 degrees is used.

The solids mass in the desorber at any given time or solids residence mass depends on the characteristics of the solids, the chamber inclination, and the rotational speed. The residence mass can be increased by attaching a "dam" or retainer ring at the discharge end. The residence time of solids is a function of the soil mass and feed rate. Preliminary tests with a given soil define the residence time for various operating conditions.

The furnace is a single refractory-lined chamber with 14 equally spaced burners controlled by a standard burner control system with appropriate safety features. Temperature measurements, which can be used for control or simply monitoring, are taken by three thermocouples attached at various locations at the inner metal wall beneath the furnace refractory. Natural gas or propane can be used as fuel. The flue gas is discharged directly to the atmosphere through a remotely positioned exhaust duct. The desorber is rated at 320,000 Btu/hr maximum heat duty. According to the manufacturer, the maximum heat transferred to the inner rotary chamber is estimated to be 100,000 Btu/hr, depending primarily on the temperature gradient between the soil (or other solids) being processed and the furnace temperature. As lime calciners, these chambers can operate up to 1400 to 1500 °F, which is well above that needed for use as a thermal desorber.

The end sections of the desorber are not enclosed by the furnace and, thus, provide considerable cooling effect. The unheated, uninsulated portion of the solids discharge section is approximately 2 feet, 10 inches. Electrical heaters placed on the off-gas plenum and the off-gas transfer pipe to the scrubber maintain a high temperature in these sections to minimize condensation of high-boiling materials before the scrubber.

Soil material exiting the rotary chamber drops through a gas plenum/transition section into a metal receiver can. An outer stainless steel drum contains the can and provides a sealed system to prevent air leakage into the desorber system. A sight glass in the discharge section of the desorber unit allows the soil flow to be visually monitored. When a can is to be replaced, the valve in the soil discharge line is closed to isolate the drum, the ring clamp seal on the drum is disconnected to allow the drum to be moved aside, and the filled can is withdrawn. Adequate inventory capacity is provided above this valve to allow the can replacement operation to be performed without interrupting the desorber feed.

3. Solvent Scrubbing Unit

The desorber off-gas (nitrogen purge with a low concentration of oxygen, volatilized moisture, and desorbed organic contaminants) is transferred through a short transition duct to the scrubber unit, where solvent removes these moisture and organic materials by cooling and condensation and absorption. If fine particulates are carried (entrained) from the desorber in the off-gas, they will also be removed. The temperatures of the off-gas and solvent leaving the scrubber are controlled between 50 and 86 °F.

The scrubber liquid flows to the receiver tank, which overflows to a larger solvent storage tank (Figure 12). The receiver has a normal liquid volume of approximately 5 gallons and serves as a separator for condensed water and particulates. The solvent enters through a dip pipe to prevent gas flow from the scrubber. A sight glass can monitor the fluid level in both the receiver and the storage tank. The level remains essentially constant in the receiver. The level in the storage tank increases or decreases, depending on the amount of solvent contained in the exhausted filter media removed during the test and the amount of water condensed. The volume of condensing water depends on the initial moisture content of the soil and the total amount of soil processed. Condensed water can be drained periodically or at the conclusion of a test.

Solvent from the storage tank is pumped with a 2-horsepower gear pump through: (1) a parallel set of fabric bagfilter units to remove particulates and (2) a shell-and-tube heat exchanger to cool the solvent to the desired operating temperature. The cooled solvent is returned to the scrubber or recirculated to the storage tank, depending on the required flow necessary for proper scrubber operation. For remote field operation, a packaged, air-cooled refrigeration unit provides chilled water/glycol to the heat exchanger.

4. Off-Gas Venting

Venting is necessary in the desorber-scrubbing process to purge accumulation of oxygen resulting from infiltration. This purge gas is routed through an emissions control unit to a stack for release to the atmosphere. A very low flow rate (3.7 to 4.8 cfm, see Table 3 in Section IV) is used. A primary adsorber consisting of about 7 pounds of activated carbon is installed to retain volatile organics in the effluent. This carbon can be changed after each test run or when the organic adsorption capacity has been reached. A comparable secondary adsorber is installed to back up the primary adsorber.

5. Solvent Photolysis Unit

The UV photolysis unit consists of a solvent storage tank, recirculation pump, UV reactor unit, and solvent cooler (Figure 13). The solvent tank has a capacity of about 5 gallons. A variable volume pump transfers solvent at 0.13 to 0.26 gpm through the cooler and to the reactor; the solvent returns from the reactor to the tank by gravity flow. A variable speed agitator mounted to the removable lid of the solvent tank is used to blend any chemical additives (e.g., isopropyl alcohol) before or during the reaction. Isopropyl alcohol (~0.05 g/g solvent solution) is used as a proton donor to minimize formation of polymeric reaction byproducts which tend to foul the light transmission surfaces (Reference 17). The tank and reactor are vented through a high-efficiency particulate air filter and carbon adsorber to prevent potential emissions.



Figure 13. Closeup of UV Photolysis Unit.

All equipment and piping in the photolysis system are constructed of Type 316 stainless steel, glass, quartz, or Teflon[®]. The entire system is designed to eliminate "dead spots" and ensure that all solvent is recirculated and can be drained from the system when a batch is completed.

The photolysis reactor assembly is a standard thin-film unit manufactured by Ace Glass, Inc. It consists of a glass reactor body (approximately 4 inches in diameter and 20 inches long), designed to promote a uniform flow of liquid film down the entire outside circumference. As a safety precaution, the reactor body is vented through a glass water-cooled condenser; normally no gas flows from the reactor system. The immersion well assembly is inserted into the reactor body and sealed to the body at the top. An annular void space exists between the immersion well and the outer reactor body. The immersion well assembly consists of two concentric quartz tubes, with cooling water circulated through the annulus. The UV lamp is inserted within the inner quartz tube, emitting radiation through both quartz tubes, the intermediate cooling water layer, and the void space to continuously expose the falling liquid film. The inner quartz tube housing the lamp is purged with nitrogen to prevent solvent vapors from entering. A high-pressure quartz mercury vapor lamp (12 inches long, 1200 watts) was used. The spectral energy distribution of the mercury lines is shown in Table 1. The stainless steel well head assembly includes a nitrogen cap and a coolant cap to seal the upper ends of the quartz tubes and provide fittings for connecting cooling water and nitrogen supply and discharge. It also contains an electrical junction box and mounting flange. The UV lamp power supply provides constant voltage. Unit controls monitor the lamp operating time. A lamp control interlock automatically shuts off the lamp and solvent recirculating pump in the event the solvent temperature is too high or cooling water to the reactor fails.

The entire reaction assembly is enclosed in a lightproof stainless steel chamber with a locked door to prevent accidental exposure to the UV radiation, which can be damaging to the eyes.

6. Hardware Modifications for JI

Modifications to the TD/UV photolysis pilot-scale hardware fell in two categories. One category consisting of six changes pertained to previous operating experience and problems encountered at NCBC; the other category consisting of three changes pertained to meeting Region IX RD&D permit requirements.

General improvement modifications consisted of the following. Their rationale is included:

- An agitator was installed at the bottom of the soil feed hopper (above the screw conveyor) to help prevent bridging and ensure uninterrupted soil flow. This was not adequate to deal with the very poor flow characteristics of the (crushed and dried) JI soil, but probably would have proved more successful with NCBC soil. Further discussion is presented in Section V.B.3.a.
- The internals inside the desorber used to control flow rate were redesigned to enable higher capacity operation (200 lb/hr vs 100 lb/hr max).
- The temperature probe inside the desorber was modified to give more temperature data points and enable better furnace control.
- The off-gas piping between the desorber and scrubber was reworked and a small particulate trap was installed. These changes were intended to ensure (a) that particulates which were entrained in the gas stream were collected in a dry form as much as possible and, (b) that the transfer pipe would not plug up. These changes were successful to a degree; however, the trap or separator could not be utilized

to its maximum potential since the superfine particles could not be drained (due to very poor flow characteristics) from the trap during operation.

- Alterations were made to the photolysis reactor to prevent misalignment of the UV lamp which occurred at NCBC.
- A different type of solvent recirculation pump in the photolysis unit was installed to better handle the tar components that accumulate in the solvent.

Permit-required modifications were the following:

- A duplicate solvent recirculation pump was installed to serve as an on-line standby to ensure that solvent flow would not be interrupted because of mechanical failure. No pump problems were encountered.
- Several emergency alarms were installed.
- A by-pass emergency vent line and large carbon canister was connected to the desorber off-gas transfer pipe in the event of emergency failure of the scrubber system.

SECTION III

PILOT-SCALE FIELD TEST METHODS AND APPROACH

A. TEST PLAN

Significant planning activities were completed to ensure safe and timely accomplishment of the project goals. These planning activities included ITC preparation of a written Test Plan/Schedule, Health and Safety Plan (Appendix E), Sampling and Analysis Plan (Appendix F), and a Quality Assurance Plan (Appendix G). These documents were submitted to EG&G Idaho/AFESC for review before the test.

The overall plan for the testing included three independent activities: soil preparation, thermal desorption operation, and UV photolysis operation. Approximately 2400 pounds of soil were planned to be prepared for the ITC process test. Soil for all the tests was prepared and analyzed for 2,3,7,8-TCDD before the first test to ensure uniform concentration. EG&G Idaho/AFESC project management designated the soil excavation locations based on results of surface soil sampling (Reference 11). Soil with high levels of contamination was used to best demonstrate the capabilities of the treatment technologies. Details of the soil preparation are presented in Section IV.B.

Four desorption tests and one photolysis test were planned. The photolysis test was to be performed separately after the desorption tests, using scrubber solvent collected from at least two consecutive desorption tests to provide a high concentration of contaminants for treatment. The testing period at JI was expected to last 1 to 2 weeks, depending on the weather and the mechanical performance of the systems. In addition, several weeks were planned to mobilize and set up the equipment and to demobilize and decontaminate the equipment. Total onsite time was projected at 4 to 5 weeks.

A series of independent desorption test runs was initially outlined, with various operating conditions selected to demonstrate the effect of key variables on treatment performance (Table 2).

TABLE 2. SUMMARY OF PLANNED DESORBER SOIL TEST CONDITIONS

<u>Run</u>	<u>Residence Time (min)</u>	<u>Temperature (°F)</u>	<u>Soil Condition</u>
1	15	1040	1/2 inch maximum
2	9	1094	1/2 inch maximum
2A	9	1022	1/2 inch maximum
3	33	1031	1/2 inch maximum

The initial run was to use treatment temperature identified through bench-scale studies and comparable to successful NCBC pilot-scale testing. This ensured achievement of the research objective of less than 1 ppb total of the tetra-, penta-, and hexa-isomers of PCDD and PCDF in the treated soil for average dioxin/furan concentrations in the JI soil feedstock. Preliminary analysis of the proposed test soil showed the 2,3,7,8-TCDD concentration to be about 80 ppb (Section IV.B), which was a third of the concentration in the NCBC soil feedstock. Therefore, shorter residence times compared to the NCBC tests were planned. Later tests were to use higher feed rates (lower residence times) and/or lower temperatures to confirm the effects on treatment performance. Also, the influence of particle size and moisture content was to be considered. These varied test conditions were intended to provide key technical information to establish the process limitations for the particular soil being treated, enable scale-up assessment of the system, and provide the basis for evaluating cost-effectiveness. The soil sizing requirement was the same as that used for the NCBC testing.

The planned test conditions for a single photolysis test were a solvent feed rate of 0.20 gpm and average solvent temperature of 90 °F. These were determined from the results of the bench-scale and NCBC pilot-scale tests (Section II.B). The goal of the photolysis field test

was to demonstrate that a 2,3,7,8-TCDD concentration of less than 1 ppb could be achieved.

All test samples were obtained onsite by Ecology and Environment, Inc. (E&E), of Kansas City, Missouri, and Buffalo, New York, and sent to ITC Analytical Services (ITAS) in Knoxville, Tennessee, for analysis. This work, performed under contract to EG&G Idaho, served as verification of test results. A limited number of sample splits were sent to Battelle Columbus Laboratories, Inc., of Columbus, Ohio, for data comparison, as part of the quality assurance/quality control (QA/QC) program. ITAS is a certified participant in the EPA Contract Laboratory Program (CLP). Although not a participant in the CLP, Battelle has performed a variety of special analytical services for EPA, including analysis for dioxins and furans. EG&G Idaho Chemical Sciences performed the validation review of data from each analytical laboratory.

B. FIELD ORGANIZATION

The ITC Quality Assurance Plan (Appendix G) established overall control under a project manager. A project leader/field QC coordinator supervised the ITC activities in the field (e.g., soil preparation, process operations, and health and safety). Also, a QC coordinator was at the Knoxville facility for the analytical activities.

E&E performed verification onsite sampling, under contract to EG&G Idaho. These activities were coordinated with the ITC project leader/field QC coordinator.

Technical monitoring in the field was provided by EG&G Idaho and AFESC project personnel. During field tests, this monitoring was around the clock, as necessary, and served to observe, direct (but not supervise subcontractor personnel), and ensure procedural compliance by the demonstration and sampling effort. The AFESC project representative was also onsite during the demonstration to provide necessary liaison between the USAF and the Defense Nuclear Agency.

C. HEALTH AND SAFETY

1. Personnel

ITC prepared a Health and Safety Plan for the JI tests (Appendix E). This plan was derived from standard health and safety procedures developed and used routinely by ITC personnel for various types of onsite activities, including the NCBC tests. It specifically addressed unique aspects of the pilot test system and JI site. The Health and Safety Plan was approved by certified industrial hygienists at both ITC and EG&G Idaho and met with EPA Region IX approval through the permit process (see Volume IV).

Although no official permissible exposure limit was in place at the time of testing for 2,3,7,8-TCDD exposure, ITC used a company-imposed limit of 18 pg/m^3 for its personnel at the JI operations. This value was based on a review of 2,3,7,8-TCDD risk assessments performed by regulatory agencies of the PCB transformer fires at Binghamton, New York, and One Market Plaza in San Francisco, California. The protective equipment requirements outlined below were specified to ensure adequate protection factors for possible exposure levels during operations. Field monitoring, discussed in Section IV.C.5, was performed to confirm the adequacy of these requirements.

Respiratory protection and protective clothing requirements were prescribed in the Health and Safety Plan (Appendix E) for three classes of work conducted within the fenced contaminated zone: (a) initial setup work such as assembling the thermal desorber; (b) contaminated soil handling such as collecting, crushing, and placing soil in the storage drums, and transferring soil to the thermal desorber; and (c) operation of the thermal desorber and UV photolysis units. Because the initial setup work would be performed in a "clean" area, all workers complied with the usual industrial safety protective clothing requirements. The setup installation was made outside the restricted perimeter; the barrier for the contaminated zone was then moved to include the test installation. The grinding room operations

in (b) required safety glasses, polyethylene-coated Tyvek[®] coveralls with hoods, white Tyvek[®] as an undergarment, nitrile gloves with surgical undergloves (leather gloves as the outer glove when working near the hot desorber), PVC boots with steel toe, and a hard hat. For desorption/UV photolysis operations in (c), the protective clothing requirements were the same as (b) except Viton[®] outer gloves were used to prevent solvent penetration. The respirator requirements depended on operating conditions in the tent and potential airborne particulates. Those involved in soil handling during the operations used supplied air or powered air-purifying respirators (protection factors 2000, 150, respectively); otherwise, full-face air-purifying respirators with organic vapor/highly efficient particulate cartridges (protection factor 50) or powered air-purifying respirators were required. Respirator requirements were subject to change, based on field monitoring by an industrial hygienist. For further details, see Appendix E.

Because the process involved release of heat and because testing was performed during July, the required respiratory protection and protective clothing could have caused personnel heat stress. Heat stress of employees on the site was monitored by the Wet Bulb Globe Temperature Index (WBGT) technique, which uses a heat stress monitoring device such as the Wibget[®] Heat Stress Monitor manufactured by Reuter Stokes. The WBGT is compared to the threshold limit value (TLV) outlined in the American Conference of Governmental Industrial Hygienists TLVs manual. Control measures to help reduce personnel heat stress were listed in the Health and Safety Plan (Appendix E). As a standard practice, ITC performed desorber/UV photolysis operations at night to provide a lower ambient temperature to reduce heat stress and allow for higher worker productivity.

2. Soil

Soil movements were conducted inside a temporary weather protection enclosure. Also, transfers were not performed in conditions of abnormally high wind. Winds were typically 10 to 15 knots.

3. Equipment

Standard operating procedures were developed and published for the thermal desorption/UV photolysis process pilot-scale unit. Detailed steps for startup and shutdown of the two processes were presented in the document. In addition, emergency procedures for immediate actions were presented in the document. Such events as various electrical power failures, desorber burner failure, nitrogen failure, coolant failure, solvent leak, and fires were covered.

The potential for fire or explosion that could conceivably result in the release of chemicals or toxic combustion products during the pilot-scale testing was minimized by equipment design and selection of fluids as follows:

- Use of a high-boiling-point solvent
- Control and monitoring of solvent temperatures
- Independent cooling loop for cooling solvent
- Containment of all solvent from high-temperature desorber unit
- Use of nitrogen as an inert gas and monitoring of oxygen concentration in the desorber purge-gas unit
- Small volumes of solvent

The solvent temperature monitoring included a high-temperature alarm to warn the operator of an abnormal condition. Equipment design safety features are discussed in Section II.C

4. Emergency Response

Because of the type of activities at JI, including the HO pilot-scale test, constant radio contact with both island safety and security personnel was required whenever activities occurred at the HO site. The emergency response section of the contingency plan is included as Appendix H.

D. VERIFICATION SAMPLES

1. Sampling

For each test run, samples were collected of the feedstock, treated soil, scrubber solvent, scrubber solvent after photolysis, and activated carbon from the emission control unit. In some cases, a composite sample representing all runs, such as solids filtered from the scrubber solvent, was collected. Collection of samples at other sample points depended on the operation, such as whether enough sample volume could be collected. All sample points are identified in the system process shown in Figure 14 by the following coding:

<u>Sample Point</u>	<u>Code</u>
Soil feedstock	01
Treated soil	02
Scrubber solvent	03
Scrubber solvent after photolysis	04
Aqueous effluent (condensate separated from scrubber solvent)	05
Solids filtered from scrubber solvent	06
Activated carbon from aqueous treatment	07
Primary activated carbon adsorber	09
Secondary adsorber	10
Process vent (emissions)	11

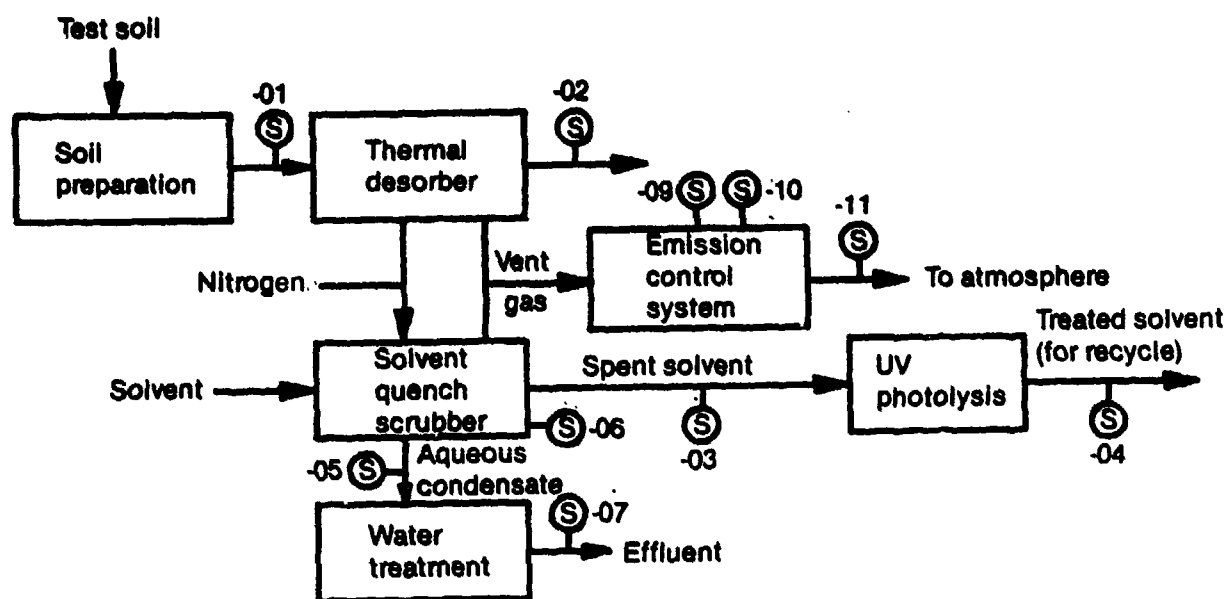


Figure 14. ITC TD/UV Photolysis Process Schematic Showing Verification Sampling Locations.

Sample Point 11 is more clearly described in Figure 15. The gas sampling train consisted of an in-line filter for particulate sampling, a port for a modified Method 5 (MM5) train for gas sampling, and a port for a volatile organics sampling train (VOST).

Sample collection and handling procedures were in accordance with EPA methods or acceptable protocols current at the time of the tests. Specific samples taken and methods/protocols followed are discussed in Section IV.D.

2. Shipping

Because of the remoteness of the JI site to the analytical laboratories, the sample coolers were shipped air freight on military aircraft to the mainland to ensure sample processing within analytical method time (shelf-life) requirements. Couriers accompanied the coolers to comply with chain-of-custody procedures and to oversee transfer of the coolers from military aircraft to express package transport services.

E. ANALYTICAL LABORATORIES

The goal for the ITC technology test was to show that treated soil meets the following criteria:

- Sum of the total isomers of tetra-, penta-, and hexachlorodibenzo-p-dioxin and the same isomers of dibenzofuran is ≤ 1 ppb
- All organics on the modified priority pollutant list (PPL) are ≤ 1 ppb (Appendix I)
- Carcinogenic organics of the modified EPA Carcinogen Assessment Group's (CAG's) list, are ≤ 10 ppm (see Appendix J)

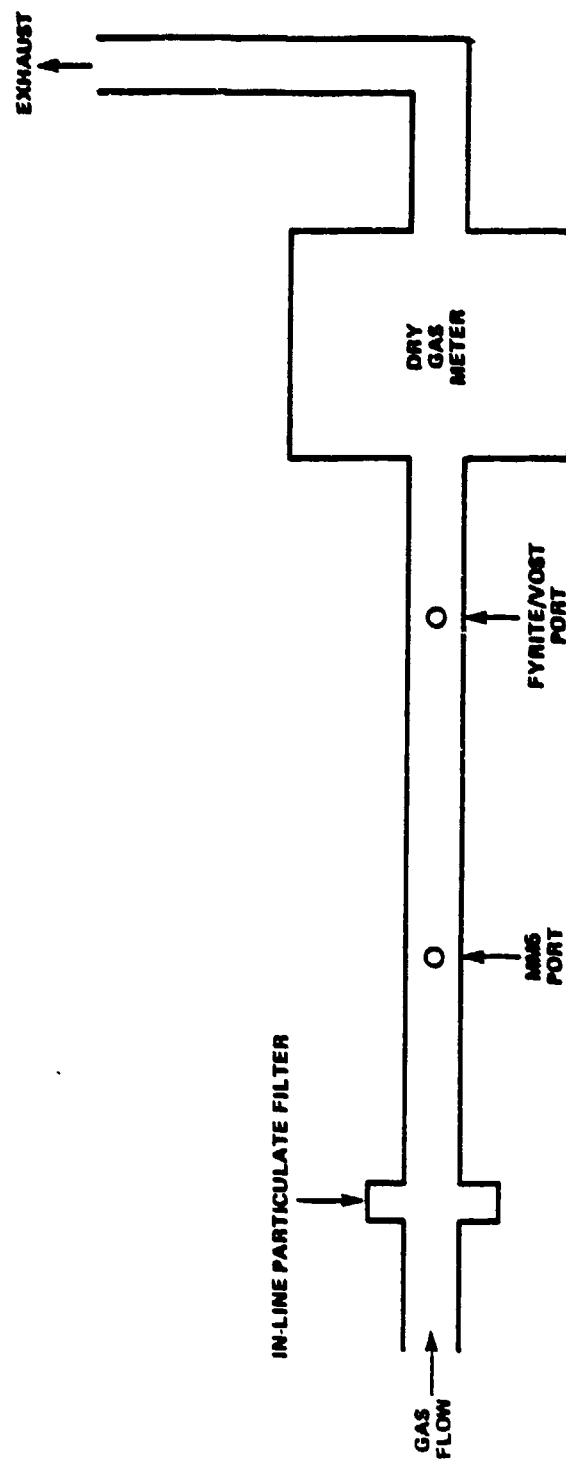


Figure 15. Sample Port Configuration on Thermal Desorber Exhaust Line.

- Organics indigenous to HO and not on PPL or CAG lists are ≤ 10 ppm (see Appendix K)
- Inorganics (heavy metals and cyanide), listed on the modified PPL (Appendix I), are quantified. If the above tests result in concentrations greater than those limits set for any of the contaminants listed in Table 1 of 40 CFR Part 261.24, then perform the EP toxicity test per Appendix B in 40 CFR 261.

Soil sample analyses by ITAS and Battelle provided data for assessment in meeting the above criteria. The following analytical detection limits were required by contract specification:

- 2,3,7,8-TCDD detection limit (DL) ≤ 0.1 ppb
- Total isomers of tetra-, penta-, and hexachlorodibenzo-p-dioxins
DL ≤ 0.1 ppb
- Total isomers of tetra-, penta-, and hexachlorodibenzofurans
DL ≤ 0.1 ppb
- Organics on modified PPL DL ≤ 1 ppm
- Modified CAG list DL ≤ 1 ppm
- Organics indigenous to HO DL ≤ 1 ppm
- Inorganics on modified PPL DL ≤ 1 ppm
- EP toxicity test per Appendix B in 40 CFR Part 261.

Achieving the detection limits for the first three limits required the capability to perform the analytical procedures with high-resolution gas chromatograph/mass spectrometer equipment.

In addition, the treated solvent, activated carbon from the vent control system, and vent emissions were analyzed for dioxins/furans, organic, and inorganic concentrations. The detection limits described above applied for these analyses as well.

ITAS' and Battelle's analytical procedures were in accordance with EPA methods or acceptable protocols. Further, quality assurance plans were associated with these analyses and were evaluated by EG&G Idaho. The methods/protocols, validation discussion, and results are presented in Section V.A.

F. WASTE STORAGE

The overall field operations plan called for waste materials generated during testing, including scrubber solvent, used protective clothing, and residues resulting from decontamination of test equipment, to be properly packaged and placed in a restricted, permitted storage area at JI. The contaminated scrubber solvent was solidified in 55-gallon drums with EMCO Imbiber beads. This plan was consistent with the conditions of the EPA permit (Volume IV). The waste inventory allowed by the permit was 20 drums of soil and spent solvent and 150 drums of aqueous cleaning residues and solid waste such as contaminated clothing.

G. TRANSPORTATION

The remoteness of JI required more extensive transportation planning compared to the NCBC demonstration. ITC equipment used conventional ground transportation between Knoxville, Tennessee, and the Pacific Coast. Movement between the mainland and Honolulu, Hawaii, was by ship. Between Honolulu and JI, movement was by barge. Replacement or missing parts were flown to JI via Honolulu. Actual weights and volumes to support the pilot-scale unit transportation are discussed in Section IV.C.

SECTION IV

FIELD OPERATIONS

A. DESCRIPTION OF SITE SETUP AND EQUIPMENT CONFIGURATION

The pilot testing at JI was performed at a location within the former HO storage site, which was selected by ITC, EG&G Idaho, and AFESC project personnel in conjunction with Defense Nuclear Agency (DNA) officials. Figure 16 is a map of the site, indicating the various principal test-related facilities. The entire site is remote from other active facilities on the island (Figure 17), and travel near the site is restricted at all times. Appropriate signs were placed at the site to identify the project and parties involved and indicate caution regarding the hazardous chemicals involved in the testing.

The area selected for placement of the pilot-scale test installation was just outside the southern perimeter of the restricted HO contaminated area. The support facilities, including the office trailer, storage crates, and the personnel decontamination trailer, were located next to the test installation (Figure 18). After setup and before actual testing with contaminated soil, the contaminated zone perimeter line was moved to encompass the pilot-scale test installation; however, the support facilities remained in the unrestricted area (Figure 16). Process and operator support equipment such as breathing air and nitrogen cylinders, propane fuel tanks, and refrigeration and air conditioning units was positioned next to the perimeter, about 30 feet from the pilot-scale process. The process equipment, including the thermal desorber skid, scrubber system skid, photolysis skid, instrument panel, electrical panel, and soil crusher, was enclosed in a fabric hangar structure for weather protection.

Figure 19 gives an approximate layout of the tent area. Within this tent, two small rooms were constructed of lumber and plastic film or insulation board. One room served as a soil preparation area to contain the dust generated during crushing operations and the other served as a

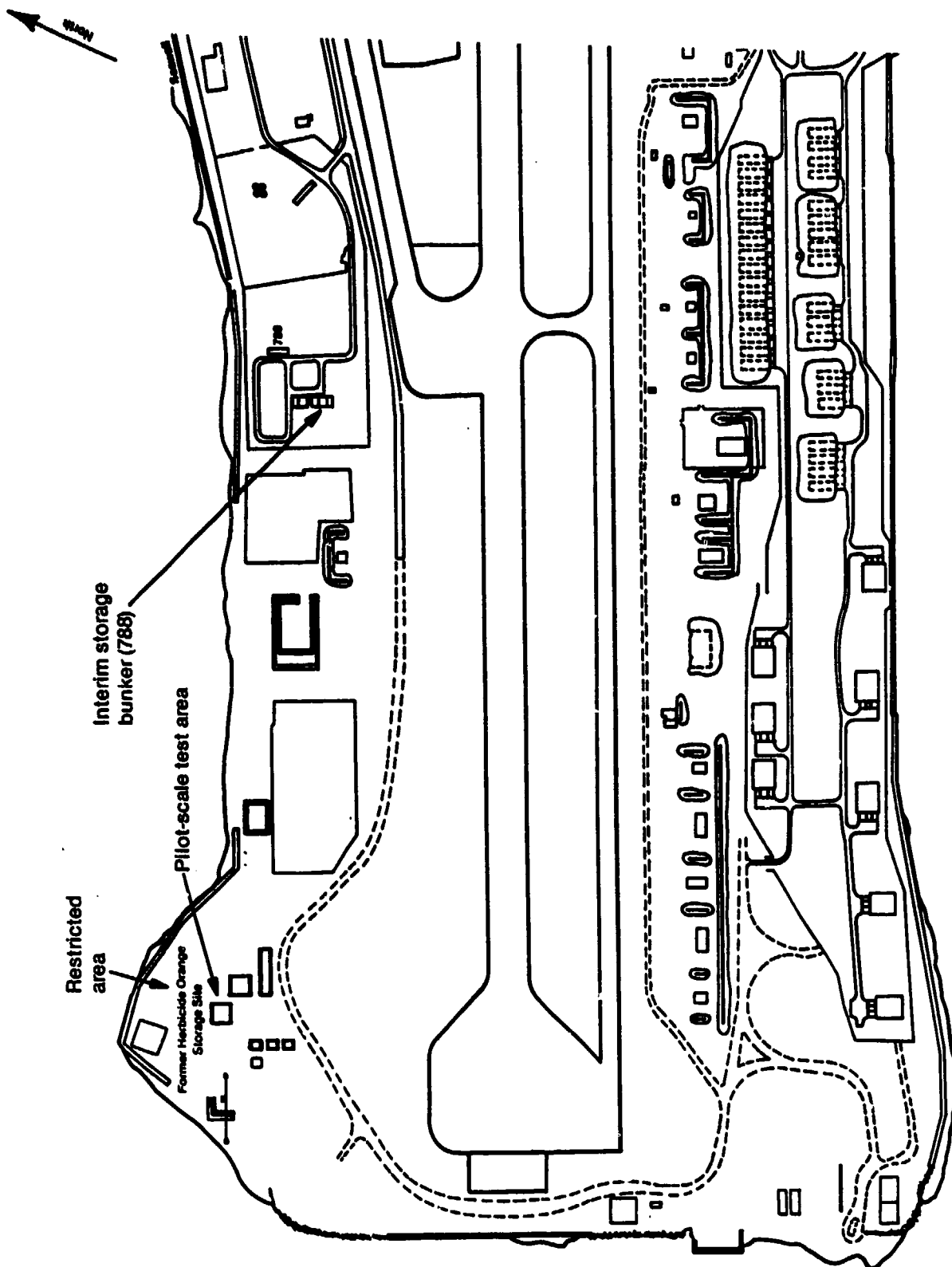


Figure 16. Map of JI Showing Former H0 Storage Site and ITC Test Installation Facilities.

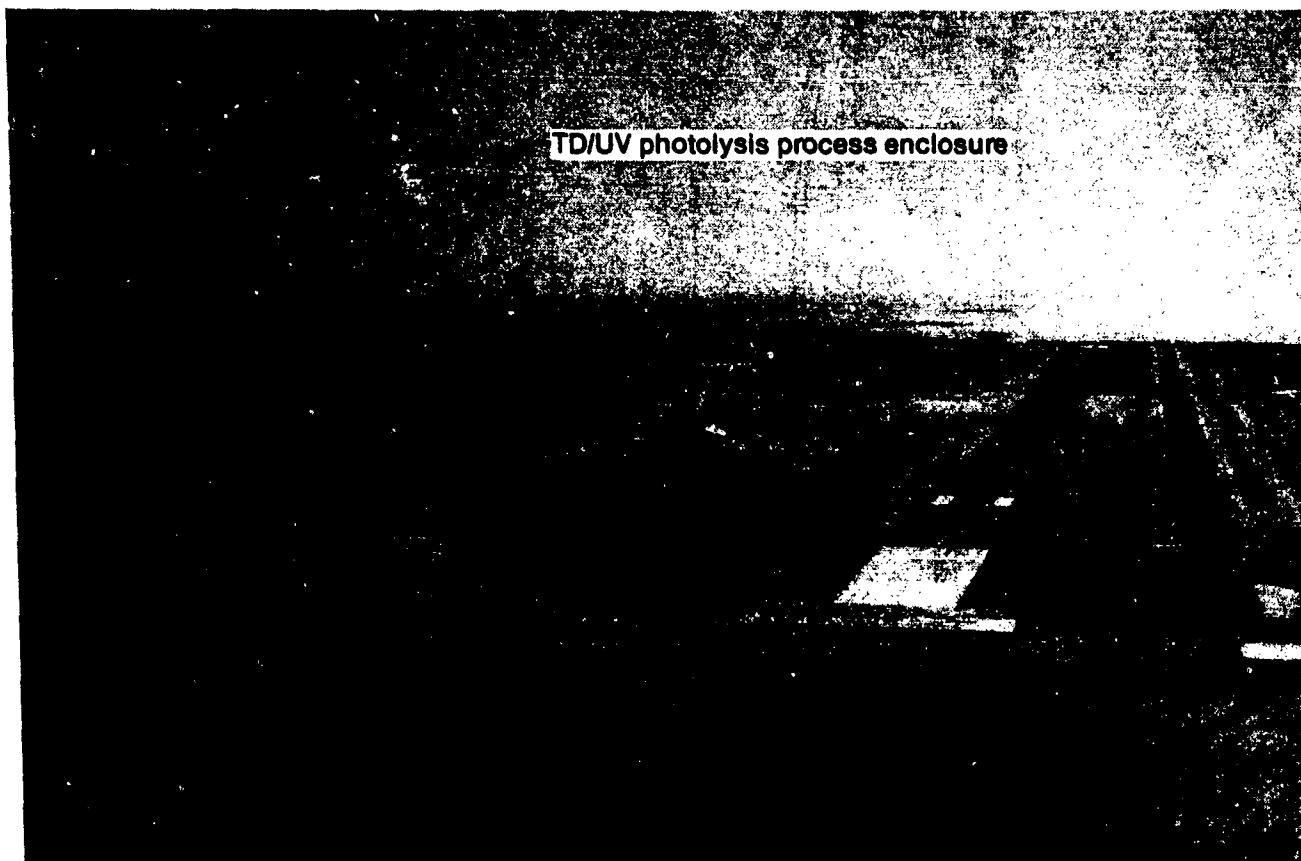


Figure 17. Aerial View of JI Showing TD/UV Photolysis Process Installation at Former HO Storage Site.

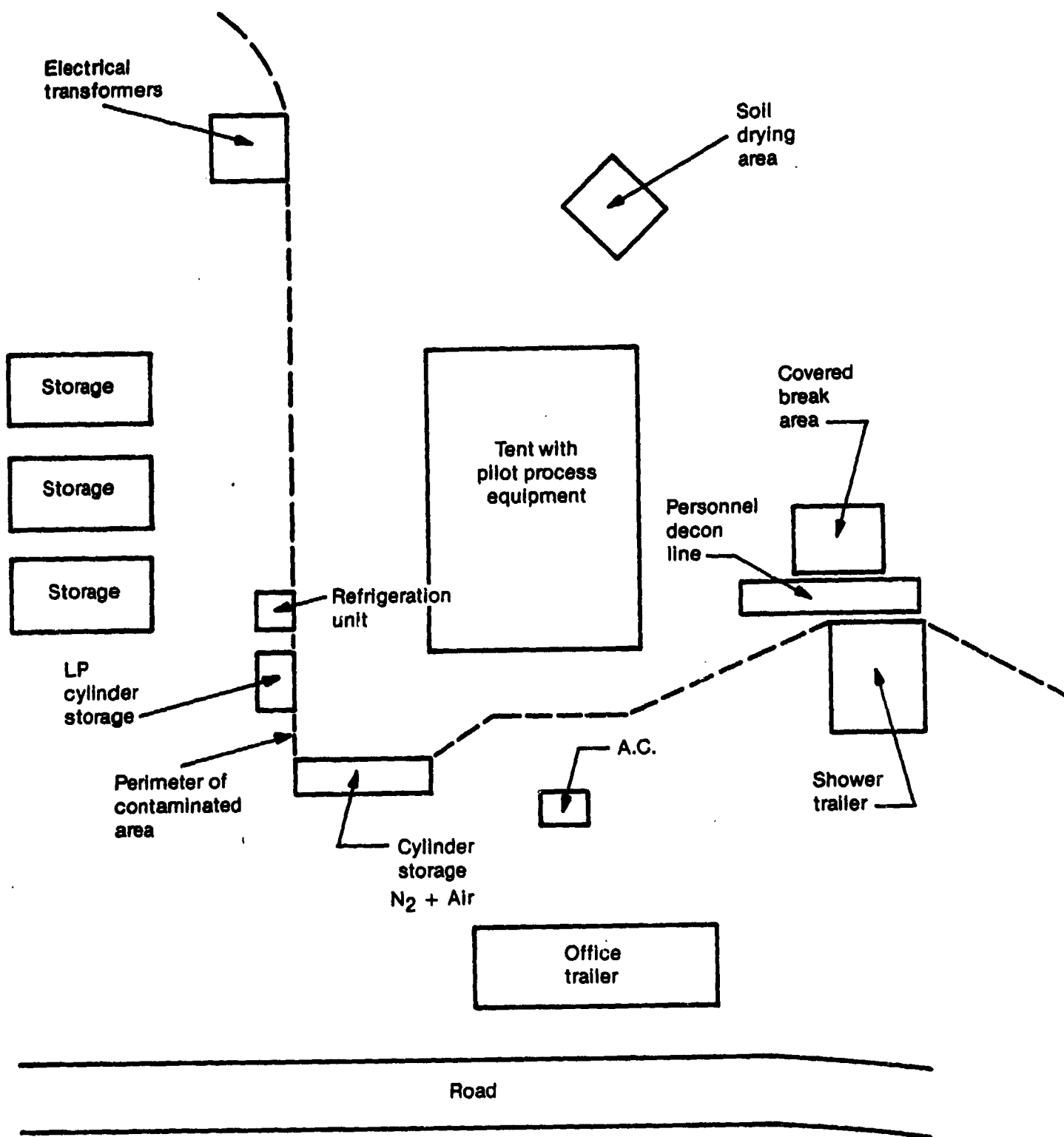


Figure 18. Site Layout of Test Facilities at JI for TD/UV Photolysis Process Pilot-Scale Demonstration.

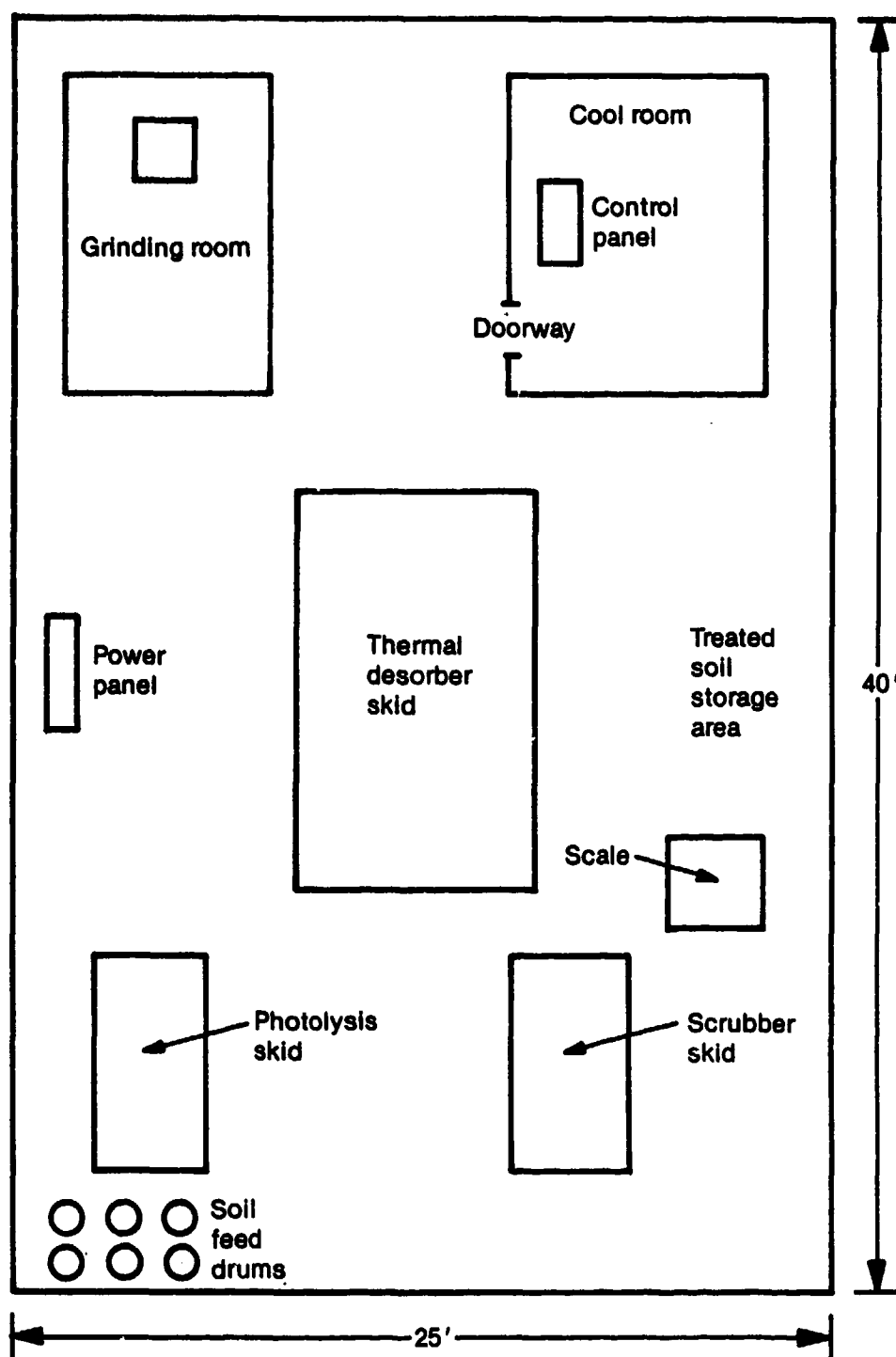


Figure 19. Layout of TD/UV Photolysis Process Pilot-Scale Equipment Inside Tent at JI.

control room. Because of the high temperatures and heat stress potential, a 5-ton air conditioner unit was placed outside the perimeter and cool air was transferred through flexible ducting into the control room. This afforded an area for operating personnel to recuperate while monitoring the instruments.

The personnel decontamination facilities were set up next to the perimeter within the restricted area. Holmes and Narver provided temporary electrical and water services from nearby utility lines.

Figure 20 shows the pilot-scale equipment in place before the frame structure of the tent was covered. Completion of the tent assembly and other parts of the ITC support area are shown in Figure 21. Figure 22 shows an overall view of the thermal desorber unit (center, rear), scrubber unit (center, front), photolysis unit (left, rear), and carbon filter (right, front).

Typical operations during pilot testing involved two to four ITC personnel within the restricted area and at least one ITC person outside this area. The person outside the area provided materials from the storage building; maintained supplies of cylinder gases, fuel, and cooling water; assisted personnel during certain aspects of donning protective clothing; exchanged information with the operating personnel; and interfaced with EG&G Idaho and AFESC project personnel and other subcontractor personnel. Work regimen to accommodate the hot weather and protective clothing initially involved 30 to 60 minute active periods with 10 to 15 minute breaks. With close monitoring of personnel by ITC's health and safety officer and with acclimation, the regimen shifted to substantially longer active periods by the completion of testing. Although the equipment and support facilities were set up during normal daytime work hours, the actual test operations were conducted after dark (6 p.m. to 6 a.m.) because of high ambient temperatures. Temporary area lighting was installed outside and inside the tent.



Figure 20. Pilot-Scale Equipment in Place before Covering Tent Structure.



Figure 21. Tent Installation--Tent, Gas Bottle Racks, Soil Solar Dryer.

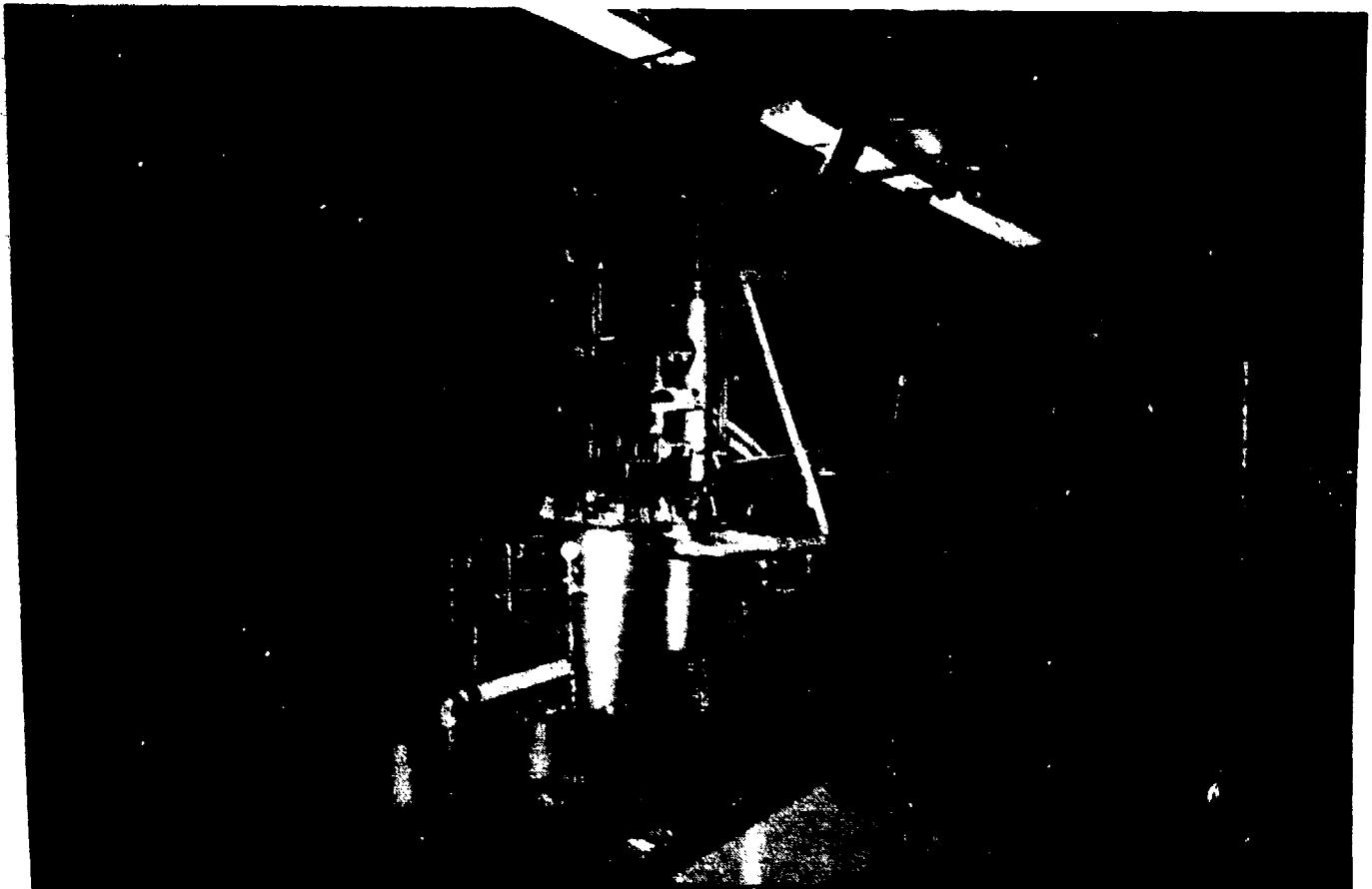


Figure 22. Overview of Installed Thermal Desorber, Scrubber, and Photolysis Units for JI Tests.

B. SOIL FEEDSTOCK

1. Selected Plots

The feedstock soil in the demonstration tests was chosen, based on results of the soil characterization study conducted in 1985 (Reference 14). Groups of grids with the highest 2,3,7,8-TCDD concentrations at the 95 percent confidence level were selected, and three soil piles (Figure 23) were excavated using a backhoe (Figure 24). Soil was excavated to approximately 8 inches at each of the three locations.

Approximately 20 aliquots were randomly collected with a tablespoon at each pile. The aliquots were composited in a disposable aluminum pan and then placed in two wide-mouth glass jars. The six samples, two for each pile, were sent to IT Analytical Services in Knoxville, Tennessee, on June 27, 1986, to determine 2,3,7,8-TCDD concentrations. Laboratory results from Piles 1, 2, and 3 were received on July 3 and were reported as 13 ppb, 65.5 ppb, and 79 ppb, respectively. Because it had the maximum concentration, the soil in Pile 3 was selected for test feedstock.

The soil from Pile 3 was then placed in eight fiberboard drums and moved to the demonstration site (Figure 25). The remaining two piles of soil were returned to the three excavations and then spread out to closely resemble the original contours.

2. Preparation for Desorber Tests

Each of the drums contained approximately 400 pounds of soil, for a total of 3200 pounds available as feedstock. Soil preparation included drying, crushing, and blending. ITC personnel placed and blended the soil in drying pans and covered the pans with a clear plastic canopy. Blending consisted of mixing soil from each drum in the pans with a hoe and shovel (Figure 26). After drying, the soil was blended further by mixing soil from each pan as it was transferred back into the fiber drums. The fiber

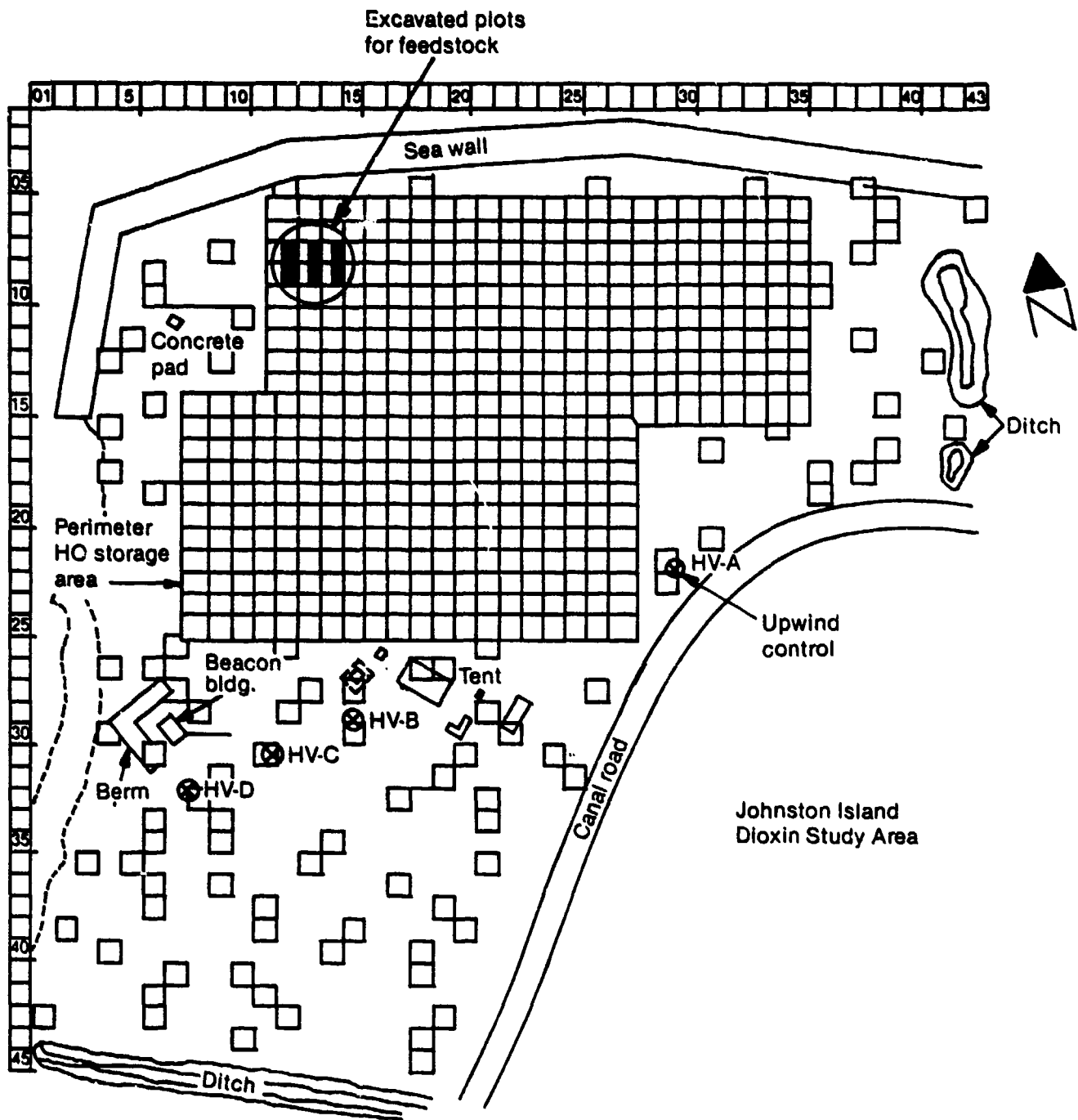


Figure 23. Excavated Plots for ITC Test-Contaminated Soil Feedstock.



Figure 24. Contaminated Soil Being Excavated for Test Feedstock.



Figure 25. Drums Containing Soil Feedstock Being Moved to Pilot-Scale Test Area.



Figure 26. Feedstock Soil Being Blended in Solar Drying Trays.

drums were taken to the grinding room in the pilot-scale test area, and the grinder crushed the soils to less than 1/2 inch.

C. FIELD ACTIVITIES

1. Overview

The onsite activities began July 1, 1986, and were completed on August 1, 1986. The initial 13 days were required to unload and assemble the tent and pilot-scale equipment; connect temporary utilities and lighting; install/construct the personnel decontamination and rest areas; place and stock the temporary storage building and office trailer; develop final detailed work schedules and plans; provide final interaction between ITC, E&E, EG&G Idaho, AFESC, Holmes and Narver and other island personnel; inspect and shake down the pilot-scale process installation, and make last-minute test preparations. Excavated soil was transported to drying trays on July 9, and grinding operations began the same day. Soil preparation activities continued until July 13.

The testing was completed during the week of July 14, 1986. The first desorption test run was performed on the first night (July 14), Test Runs 2 and 2A were performed on the second night, and Test Run 3 was performed on the fourth night. The photolysis test was performed in two stages on the third and fourth nights. E&E personnel took verification samples for each test run and shipped them to the analytical laboratories. The final 2 weeks onsite were used to disassemble and decontaminate all pilot-scale equipment; pack and load all equipment and materials; and package, label, and place all waste materials in permitted interim storage.

2. Test Procedures

For each desorber test, the normal operating sequence included the following steps:

- Solvent was transferred from drums to the scrubber unit, which was sealed and leak-tested.
- The solvent cooling unit was started.
- The scrubber unit was started and adjustments made to achieve proper conditions (flow, temperature, and pressure).
- The nitrogen purge and off-gas systems were started and adjusted.
- The desorber was started. Adjustments to the desorber rotational speed and soil feed conveyor speed were made to achieve desired throughput. Flow rate was measured by collecting and weighing the soil exiting the desorber during a specified time. Residence time was measured by injecting colored gravel into the feed conveyor and observing the time until it appeared at the desorber discharge.
- The desorber furnace was started.
- Adjustments to the burners were made to achieve the desired soil test temperatures.
- After a short period of steady-state operation at test conditions, the test was started, during which time a composite sample of treated soil was taken.
- The test period was stopped.
- Soil feed was stopped and the desorber was allowed to empty.
- The furnace was shut down and the desorber was allowed to cool.

- The desorber, scrubber unit, and off-gas/purge system were shut down.
- After Runs 2A and 3, the solvent tanks were partially drained to collect and isolate any discrete aqueous phase that had collected. Then the scrubber system was completely drained and flushed (with Soltrol[®]). Solvent representing Runs 1, 2, and 2A was collected in a drum for use in the photolysis test.
- The activated carbon from the vent control system was removed from the primary adsorber and replaced with new carbon. Activated carbon from the secondary adsorber was removed only after all desorber tests were completed.

For the photolysis test, the normal operating sequence consisted of the following steps:

- The cooling unit was activated.
- Scrubber solvent was weighed and transferred from the designated drum to the solvent tank.
- Isopropyl alcohol was weighed and added to the solvent (Section II.C.5), and agitation in the solvent tank started.
- Solvent flow to the reactor was started and adjusted; the reactor was aligned to achieve uniform flow distribution.
- The reactor enclosure was closed.
- The UV power supply and lamp were activated.
- At designated times, solvent samples were taken.

- At the designated total operating time, the power supply was shut off.
- The final treated solvent sample was taken.
- Solvent flow to the reactor was stopped and agitation in the solvent tank was stopped.
- The entire system was drained and flushed and the reactor was cleaned.

3. Test Conditions

Process monitoring data were taken throughout the desorption and photolysis tests to determine if test conditions were appropriate and if the processes were performing as designed. Adjustments were made during the tests to correct deviations from operating conditions. Process monitoring data included temperatures of the desorber unit, soils, solvent system, and off-gas; soil feed rates; fuel feed rates; system pressures; and off-gas flow rates.

The average operating parameters for each of the four desorption test runs are summarized in Table 3. The final selection of time-temperature conditions for all runs was based on: (a) the actual measured concentrations of 2,3,7,8-TCDD in the prepared test soil, (b) the ITAS results of laboratory shakedown tests on uncontaminated JI soil, and (c) the results of onsite shakedown tests. The installation by IIC in Knoxville of a new desorber feed mechanism after the NCBC demonstration greatly increased the feed rate capabilities for the JI tests. The new feed mechanism increased the rate capability from 97 lb/hr to approximately 220 lb/hr. Temperatures used at JI were approximately the same as those at NCBC except for Test Run 2A, which was higher.

TABLE 3. SUMMARY OF OPERATING PARAMETERS FOR FOUR PILOT-SCALE
DESORPTION TESTS AT JI

Parameter	Test Number ^a			
	R1	R2	R2A	R3
Soil feed rate, lb/hr	99.0	193.6	209.0	50.6
Soil residence time, min				
Furnace	9.6	5.6	5.6	20.5
Total	15.5	9	9	33
Soil temperature, °F ^b	1049	1094	1022	1031
Operating time, hr				
Test period ^c	1.75	4.5	1.0	4.0
Total	6.75	7.0	2.0	7.25
Total soil processed, lb	586	1034	271	290
Vent gas flow, cfm	3.77	4.43	4.74	3.90
Negative pressure in desorber, inches water	-0.25	-0.45	-0.35	-0.25
Oxygen concentration in scrubbed off-gas, %	2.9	3.3	2.2	4.8
Solvent temperature to scrubber, °F	50	59	54	54
Solvent flow to scrubber, gpm	4.2	4.2	4.2	4.2

a. Total solvent charge for each test was approximately 14 gallons.

b. Soil feed temperature was measured at three points that were controlled within ± 16 °F of average value indicated.

c. Test period defined as steady-state period during which a discrete treated soil sample was collected; R2 and R3 took longer because of the time required to collect a vent gas sample.

TABLE 4. SUMMARY OF OPERATING PARAMETERS FOR COMPOSITE
PHOTOLYSIS TEST AT JI

Parameter	Test Run Value
Quantity photolyzed, gal ^a	2.2 ^b
Total operating time, hr ^c	13.5
Average solvent temperature, °F	90
Average solvent flow, gpm	0.20

a. Isopropyl alcohol (IPA) charge for all runs was 5% (1 lb).

b. Represents solvent from desorber Test Runs 1, 2, and 2A.

c. Actual UV exposure or reaction residence time is significantly less than operating time.

The primary operating conditions for the photolysis test are given in Table 4. These conditions are comparable to those used during the photolysis tests at NCBC.

4. Health and Safety

a. Personnel Protection

Protective clothing and respiratory protection requirements varied for different types of activities. During setup activities before disturbance, handling or processing of contaminated soil, using air-purifying respirators, were not required. For soil handling and grinding, powered air-purifying respirators were used. Supplied-air respirators were not determined to be necessary because there was no visible dust. For operation of the thermal desorber or UV photolysis systems, powered air-purifying respirators were also employed. Protective clothing during setup included safety shoes, work gloves, and eye protection (safety glasses). Protective clothing for soil handling and grinding and process

operation included white uncoated Tyvek[®] coveralls as undergarments, polyethylene-coated Tyvek[®] coveralls with hoods, hard hats, polyvinyl chloride (PVC) safety boots with steel toes, surgical undergloves, and nitrile gloves or Viton[®] gloves (for use with solvent).

b. Industrial Hygiene Monitoring

The ITC Health and Safety representative monitored the operating personnel for heat stress, inspected the test area and identified health and safety hazards, verified levels of protective clothing, and ensured compliance with the site Health and Safety Plan (Appendix E). ITAS conducted atmospheric monitoring using personal air sampling pump and filter systems. Samples were taken near the various types of work activities to determine the exposure levels of workers to 2,3,7,8-TCDD. Details of the sampling procedure are presented in Appendix E. These samples were packaged and shipped along with the verification samples (Section IV.D) to ITAS for analysis. A summary of the industrial hygienist's report on the overall monitoring results is presented below (see Appendix L for details).

No 2,3,7,8-TCDD was detected in any of the five personnel atmospheric monitoring samples. Two samples covered soil grinding operations from July 12 to 13. Detection levels for these two samples were 1750 and 1842 pg/m³. The other three samples covered thermal desorber operations of July 14-16, including soil loading. Detection levels ranged between 546 and 701 pg/m³. Because all operations personnel wore individual powered air-purifying respirators, with a protection factor of 150, the 2,3,7,8-TCDD exposure was less than the company-imposed limit of 18 pg/m³ discussed in Section III.C.1.

Heat stress readings were taken throughout the pilot-scale activities and indicated a need for a very moderate work regime. The new NIOSH guidelines for heat stress utilized a Wet Bulb Globe Temperature (WBGT) index along with physiological monitoring (oral temperature and pulse). One operations employee became ill from heat in full protective

gear, but recovered after decontamination and rest. He was monitored closely for the duration of the demonstration with no further problems. None of the other personnel exhibited heat stress problems.

Noise and isopropyl alcohol measurements (during UV photolysis) were not taken during the JI test operations because measurements taken during the NCBC test showed that the levels were acceptable. Hearing protection was provided and worn during the grinding operations.

c. Medical Examinations

All ITC personnel received a medical examination before the JI demonstration test. The followup examination will be within 1 year of the previous examination according to ITC's Corporate Safety Program.

5. Equipment Decontamination

At the completion of all test activities, equipment was decontaminated according to prescribed ITC procedures (see Appendix F). The solvent scrubber loop and UV photolysis unit were flushed and hand-cleaned with solvent. A high-pressure hot water washing was then applied to all process equipment and tools that had been inside the restricted area (Figure 27). Nonsoapy exterior surface waters were discharged to contaminated areas of the HO site. Electrical equipment was cleaned with Freon[®] (Figure 28). Items were then wrapped in plastic film. Articles made of permeable materials, such as rubber wheels, tent fabric, and hose, plus grease-laden mechanical parts such as drive chains, were discarded as contaminated waste materials. Construction materials used in the contaminated area, including plastic film and lumber, were considered contaminated because decontamination and wipe sampling was impractical.

Wipe samples were taken on each major equipment item, and composite samples were taken of collected small items. An area of about

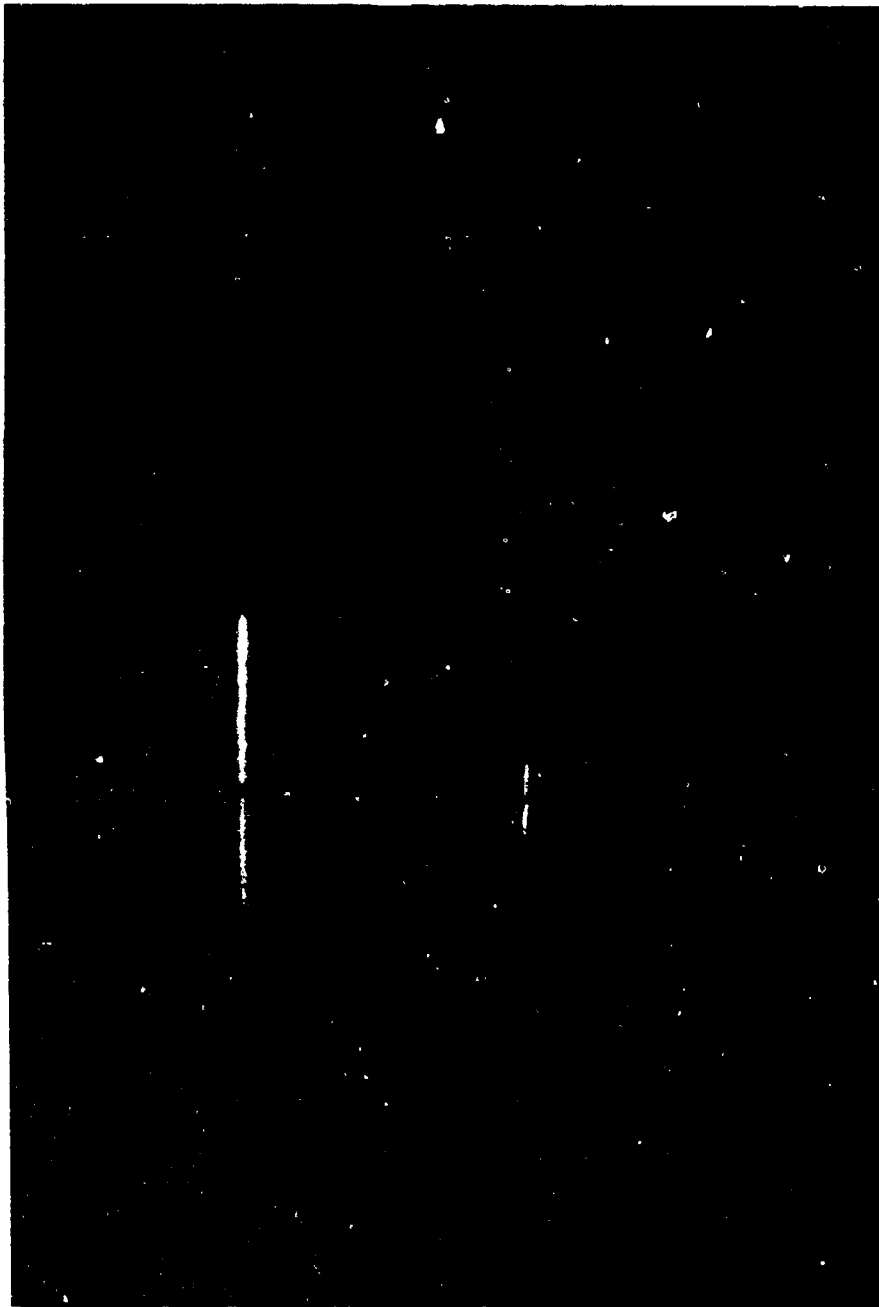


Figure 27. Equipment Being Decontaminated by High-Pressure Water Wash.

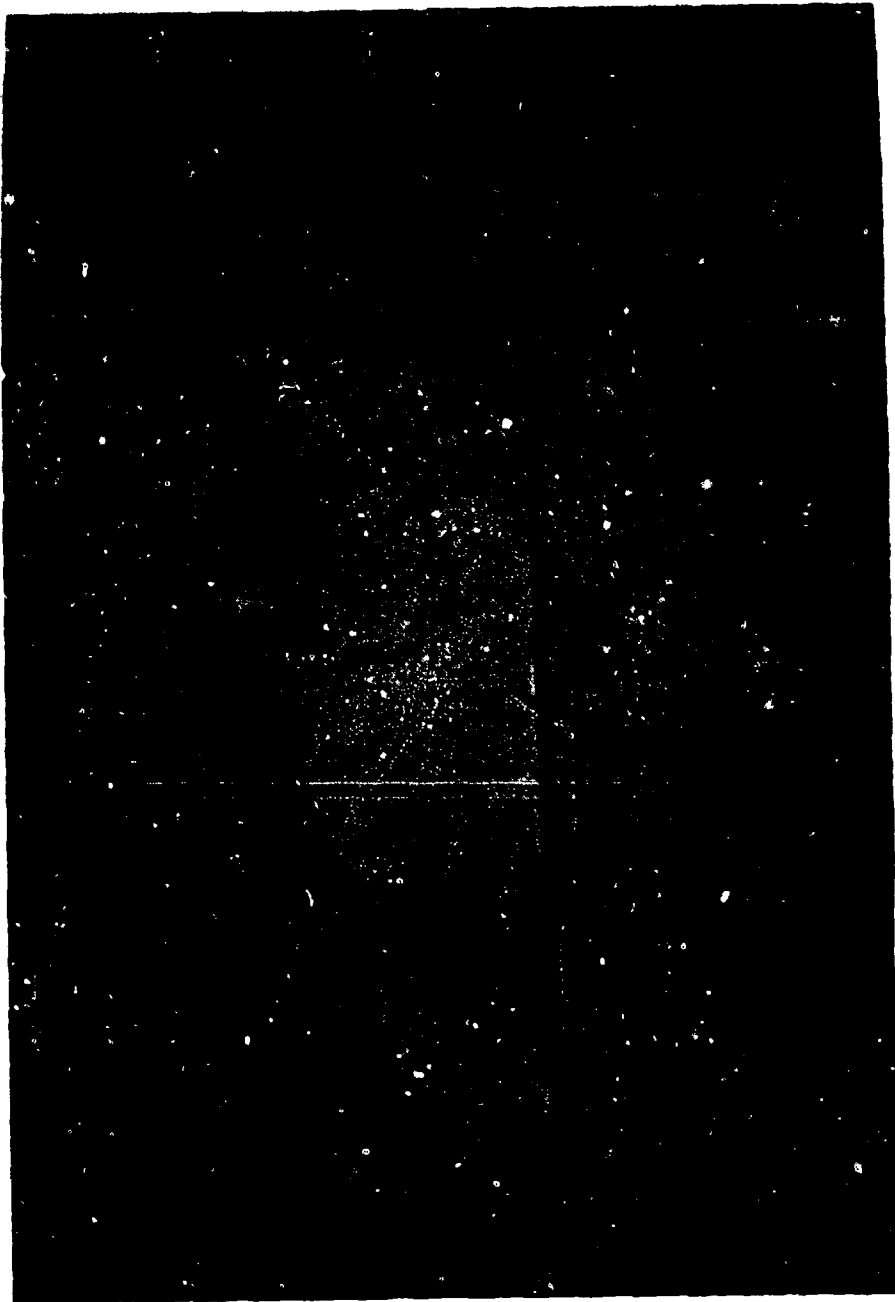


Figure 28. Electrical Equipment Being Decontaminated by Freon[®] Spray.

10 inches by 10 inches was used for the wipe tests. A total of 10 samples, designated as JI-W01 through -W10, were initially taken. These samples were packaged and shipped, along with the verification samples (Section IV.D) to ITAS for rapid 2,3,7,8-TCDD analysis to support closure of test operations at JI.

Analysis for 2,3,7,8-TCDD showed all but three samples to be less than the 100 ng/m^2 cleanup criterion prescribed by ITAS's toxicologists. These three samples ranged from 180 to 410 ng/m^2 . The two highest values were from process equipment sections that were in direct contact with contaminated soil or solvent. These items were recleaned and resampled (designated JI-W11 through -W14). These results showed the criterion was met. Detailed analytical results are presented in Appendix M.

6. Waste Storage

Waste materials generated during the onsite activities were grouped according to category, put into containers, labeled, and transferred to Bunker 788 (Figure 29), which is located in a restricted storage area on JI (Figure 13). Waste categories included spent scrubber solvent, which was solidified using a polymeric adsorbent (EMCO Imbibor Beads); used protective clothing and respirator cartridges; trash, tent fabric, plastic film, and other miscellaneous construction materials; and process equipment items identified above which could not be decontaminated. A small compactor was used to minimize the waste volume.

The inventory and RCRA code of wastes added to the bunker storage because of this test demonstration were as follows:

- 58 fiber drums-F027
- 5 55-gallon drums-F027
- 3 55-gallon drums-F027 (solidified solvent)
- 4 55-gallon drums-F028 (treated soil)

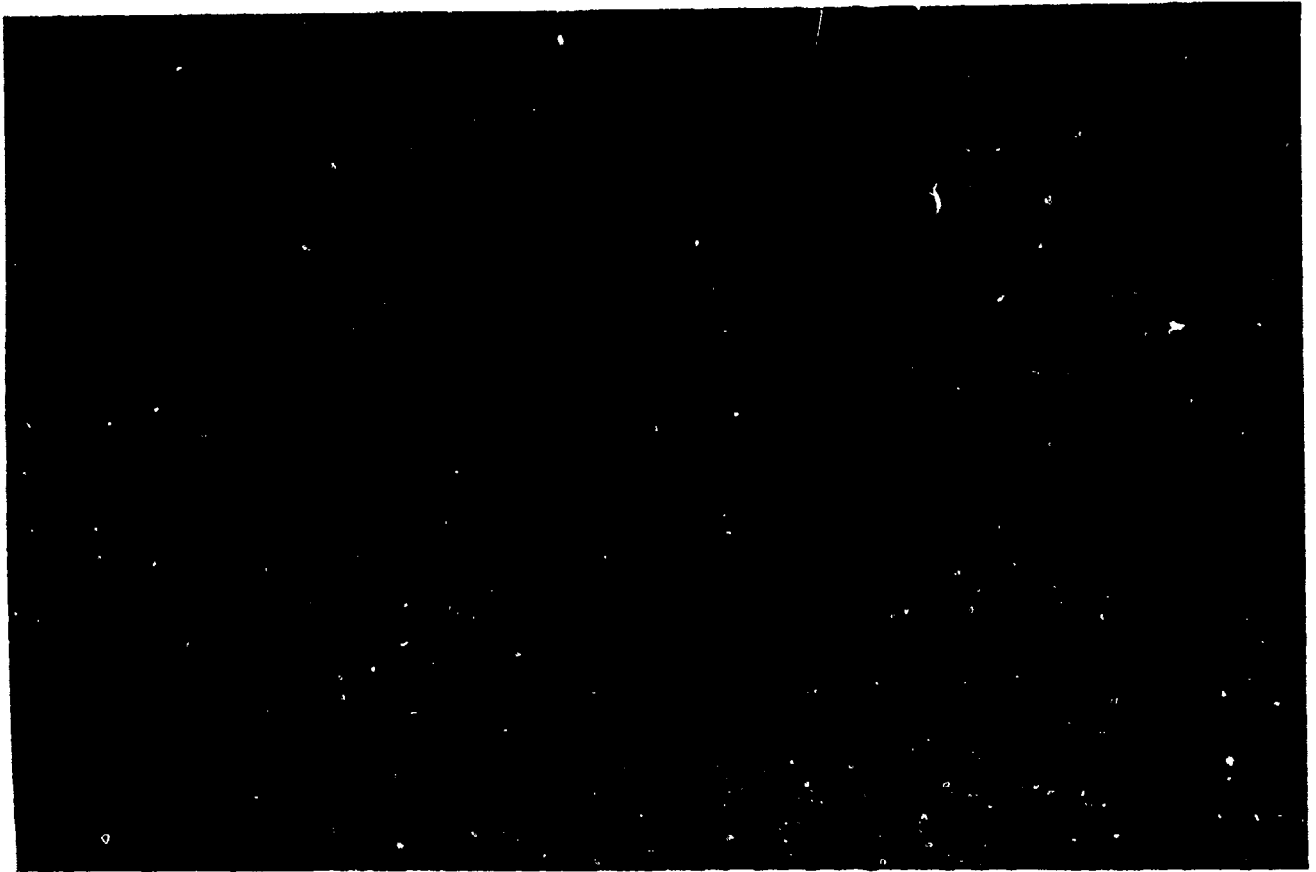


Figure 29. Waste Storage at Bunker 788 on JI.



Figure 30. Waste Drums from Demonstration Test Stacked Within Storage Bunker 788.

These quantities were well within the permit limits. Figure 30 shows the drums stacked within the storage bunker. The three drums containing the solidified solvent are shown on the right placed within a galvanized steel drip pan. The four drums containing the treated soil are shown in the center front.

7. Transportation

In addition to representatives from EG&G Idaho (1) and AFESC (2), subcontractor personnel were flown to and from JI for the test. ITC had a basic crew of six personnel from Knoxville, Tennessee, to support soil preparation and TD/UV photolysis process operations over the test duration. An industrial hygienist was onsite for 1 week to perform personnel monitoring. Two people from E&E's Kansas City, Missouri, operation stayed for the test duration to perform soil, other material, and ambient air sampling and to perform waste packaging. An additional three E&E personnel from its Buffalo, New York, operation were onsite for a brief period to take the vent gas samples.

Material supporting the JI testing was provided from the AFESC Gulfport operation or ITC in Knoxville, and was shipped overland to Holmes and Narver in Oakland for shipping to Honolulu. The material from Gulfport consisted of one decontamination trailer (3460 lb, 1392 ft³) and one lot of three crates and many loose items (6900 lb, 1210 ft³). The ITC material consisted of one pallet of four cylinders containing propane (hazardous cargo) and 13 crates of materials and equipment (19,029 lb, 2627 ft³). An example of loading of an equipment crate is shown in Figure 31. At Oakland, additional leased items were loaded. This included a Space Master office trailer (6000 lb, 2028 ft³), 85 gas cylinders (18,683 lb, 965 ft³), and three crates of materials and equipment (7350 lb, 954 ft³). The gas cylinders consisted of:

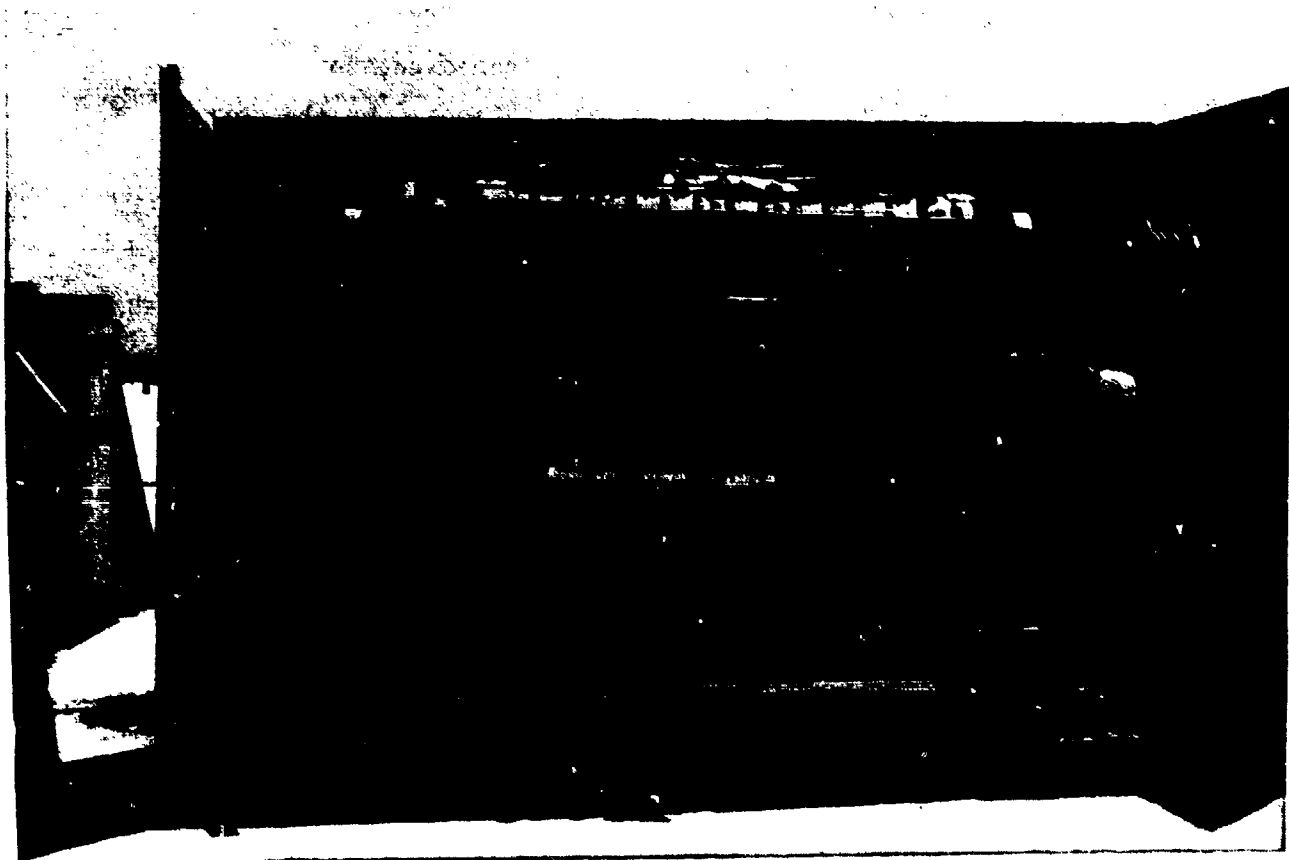


Figure 31. Typical Crating of Equipment for Demonstration at JI.

<u>Fluid</u>	<u>Number of Pallets</u>	<u>Hazardous Cargo</u>
Flammable hydrogen gas	1	yes
Liquefied petroleum gas	2	yes
Acetone	1	yes
Denatured alcohol	1	yes
Nitrogen gas	4	no
Compressed air	1	no

The total hazardous cargo being shipped to JI from Oakland and return was approximately 11 pallets and crates (9233 lb, 940 ft³). Items other than the two trailers were loaded in two Matson vans (8350 pounds and 11,000 pounds, 1415 ft³ each, see also Figure 32). On the trip to JI, a third Matson van was loaded with consummables or equipment that were left at JI. This van was not used by the project on the return trip.

A small amount of materials and spare parts were flown from F&E and ITC to JI. This amounted to approximately 300 to 400 pounds.

8. Site Certifications

The EPA RD&D permit for the JI demonstration test required submitted certifications for the following: (a) construction for the test was in compliance with the permit, and (b) closure of the test was completed in compliance with the permit. A copy of each certification is in Appendix N (Exhibits 1 and 2).

D. THIRD-PARTY SAMPLING

1. Methods/Protocols

For each of the list samples of solids (soil, carbon, or filter solids), two 8-ounce, wide-mouth jars were filled with the sample material. Samples were taken by thoroughly blending the material and taking a number of aliquots, using a metal spoon to produce a representative composite. For scrubber solvent and aqueous condensate, 8-ounce, amber,



Figure 32. Shipping Containers Used for Transportation of Material
for Demonstration at JI.

wide-mouth bottles were used. For these liquid samples, the sampling line was purged and the tank contents were blended before taking the sample. A process vent gas sample was also collected during Tests R2 and R3. The sampling protocols in Appendix O provides the procedural details.

Vent gas sampling was conducted for particulate state 2,3,7,8-TCDD and isomers of PCDD/PCDF and total particulates using an in-line filter. Gaseous phase 2,3,7,8-TCDD and isomers of PCDD/PCDF were collected using a MM5 train equipped with a XAD-2 resin sorption bed, as described in EPA Method S008 (Reference 23). Volatile organics were sampled with a Nutech Model 280 VOST. Six pairs of cartridges (i.e., Tenax[®] and Tenax[®]/charcoal) were collected during each run at approximately half-hour intervals. Gas stream temperatures were monitored using thermocouples attached to the MM5 train. Gas analysis was conducted using a Figrite analyzer to monitor percent O₂ and CO₂. Hydrogen chloride was collected in the MM5 train. All sampling was collected at the approximate center of the vent line. Sampling was conducted for each of the above parameters simultaneously, over a period of about 3 1/2 hours, using the configuration shown in Figure 15. The sampling protocols in Appendix P provide the procedural details.

All samples for analysis were sealed, packaged, and shipped to ITAS in Knoxville. Samples were preserved during and following shipment by ice packs or refrigeration. Courier-accompanied sample shipments were made on June 8 and July 19 and 26. Figure 33 describes the containers used. As part of the project quality assurance plant, several split samples were taken and forwarded to Battelle Columbus Laboratories in Columbus, Ohio. For samples being sent to the Knoxville Laboratory, an ITC representative took possession at Travis Air Force Base, California. Samples to Battelle were shipped from Travis via Federal Express, which performed the function of courier.



Figure 33. Coolers Used to Ship Verification Samples.

2. Material Samples

E&E, in cooperation with ITC's operating personnel collected a variety of liquid, solids, and gas samples from the desorption and photolysis tests at JI. Figure 14 identifies the process sample points. All the samples taken are identified in Table 5. Feedstock and treated soils were sampled during each desorption test. Solvent samples were taken after each desorption test run and during the photolysis test. The process vent was sampled during Tests 2 and 3.

Figure 34 shows a treated soil sample being prepared. The cans in the background contain the treated soil from the different test runs. Figure 35 shows a gas sample being taken.

3. Ambient Air Particle Samples

E&E ambient air monitoring was conducted during the TD/UV testing activities from July 9 through 28, 1986. Three sample sets were taken corresponding to the following activities:

<u>Sample Set</u>	<u>Dates</u>	<u>Activities</u>
1	July 9-11	Setup and testing
2	July 12-20	Equipment operation
3	July 21-28	Decontamination and demobilization

The site activities monitored during Sample Set 1 occurred during daylight hours and did not involve the handling of the contaminated materials. The activities monitored during Sample Set 2 occurred during the night and involved the handling of contaminated materials. Sample Set 3 monitored daytime decontamination and dismantling of materials, activities considered to be potentially contaminated.

TABLE 5. IDENTIFICATION OF VERIFICATION SAMPLES TAKEN AT JI

<u>Sample Description</u>	<u>Code</u>	<u>Identification</u>
Soil feedstock after preparation	01	IT-JI-R1A-01 ^a R1B-01 ^a R1B-01B ^b R2-01 R3-01
Treated soil	02	IT-JI-R1A-02 R1B-02 R1B-02B R2A-02 R2A-02 ^b R2B-02 R2B-02A ^c R3-02 R3-02A ^b
Scrubber solvent	03	IT-JI-R1-03 R1-03A ^d R1-03B ^d R1-03C ^d R2-03 ^e R3-03
Scrubber solvent after photolysis	04	IT-JI-R1-04 R1-04A ^c R1-04B ^b
Aqueous effluent condensate separated from scrubber solvent)	05	IT-JI-02-05 (composite)
Solids filtered from scrubber solvent	06	IT-JI-R1-03-06 (composite of all tests)
Activated carbon from aqueous treatment	07	No water treated; no sample
Description system vent	08	No sample

TABLE 5. IDENTIFICATION OF VERIFICATION SAMPLES TAKEN AT JI (CONCLUDED)

<u>Sample Description</u>	<u>Code</u>	<u>Identification</u>
Activated carbon from vent control system		
Primary adsorber	09	IT-JI-R1-09 R2-09 R3-09
Secondary (guard absorber)	10	IT-JI-R1-03-10
Process vent (emission)	11	IT-J1-R2-11-1/15 ^f

a. A and B refer to first and second portions of the "test period."

b. B refers to the sample split sent to Battelle.

c. A refers to field duplicate sample.

d. A, B, and C refer to different consecutive time intervals during photolysis Test R1.

e. Sample split with same number sent to Battelle.

f. Multiple samples representing the various portions of the stack sampling train and field blanks.



Figure 34. Treated Soil Sample Being Taken.

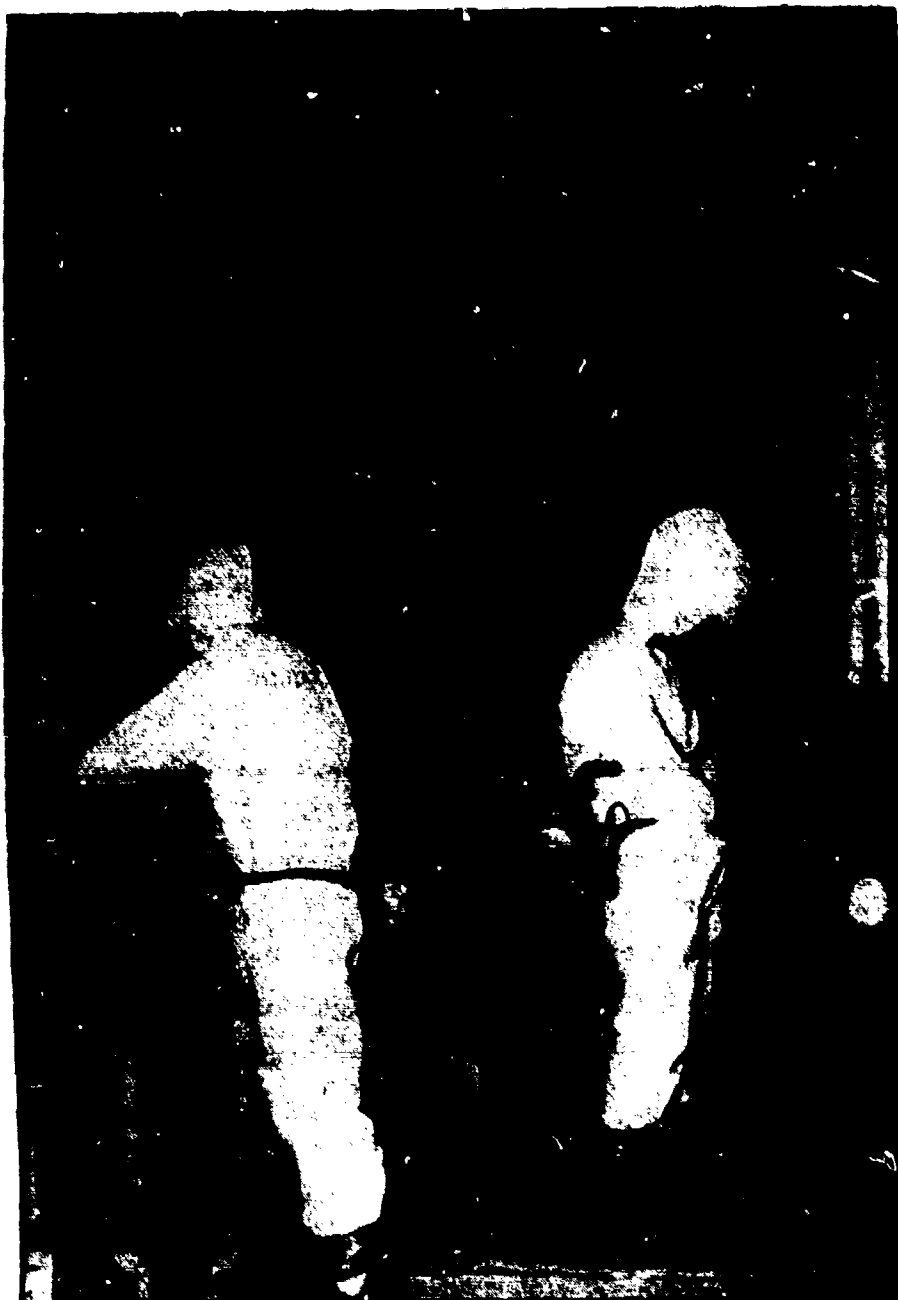


Figure 35. Gas Sample Being Taken.

To determine any impact from the activities, four high-volume air particulate samplers were positioned to provide control and exposure data. The layout of the samplers, shown in Figure 36, was based on a prevailing easterly trade wind direction. Sampler HV-A was positioned upwind from the test installation to provide offsite control data (Figure 37). Samplers HV-E, HV-F, and HV-C were positioned in a line from the test installation at 80-foot intervals (Figure 38) to obtain exposure data as a function of distance.

The locations for the downwind samplers were determined by using a simple Gaussian plume dispersion model. The model calculated the distance downwind where the maximum ground level particulate impact could be anticipated. The sampling locations were adjusted about 20 feet closer to the project tent than the model predicted. This was done to prevent radiant heat damage to the samplers from the use of an Army rocket fuel disposal area about 300 feet southwest of the site and to compensate for the intake height of the samplers above the ground.

The dispersion model utilized the exhaust stack of the demonstration process as an emission point. The stack was situated about 15 feet above the ground surface. An average wind velocity of 11 miles per hour blowing parallel to the island's runway (60 degrees) was also used. Pasquill-Gifford Stability Class A (unstable) conditions were assumed for measuring contaminant migration during daylight activities, and Stability Class D (neutral) conditions were assumed for measuring nighttime activities (Reference 35).

During Sample Set 1 and because of unstable air turbulence, Sampler HV-E (80 feet downwind) was used to monitor offsite migration (maximum impact), and Sampler HV-C (240 feet downwind) was used to monitor for TCDD leaving the island. Upwind Sampler HV-D functioned as a control sampler. Sampler HV-F (160 feet downwind) also acted as a control to monitor offsite migration due to natural processes.

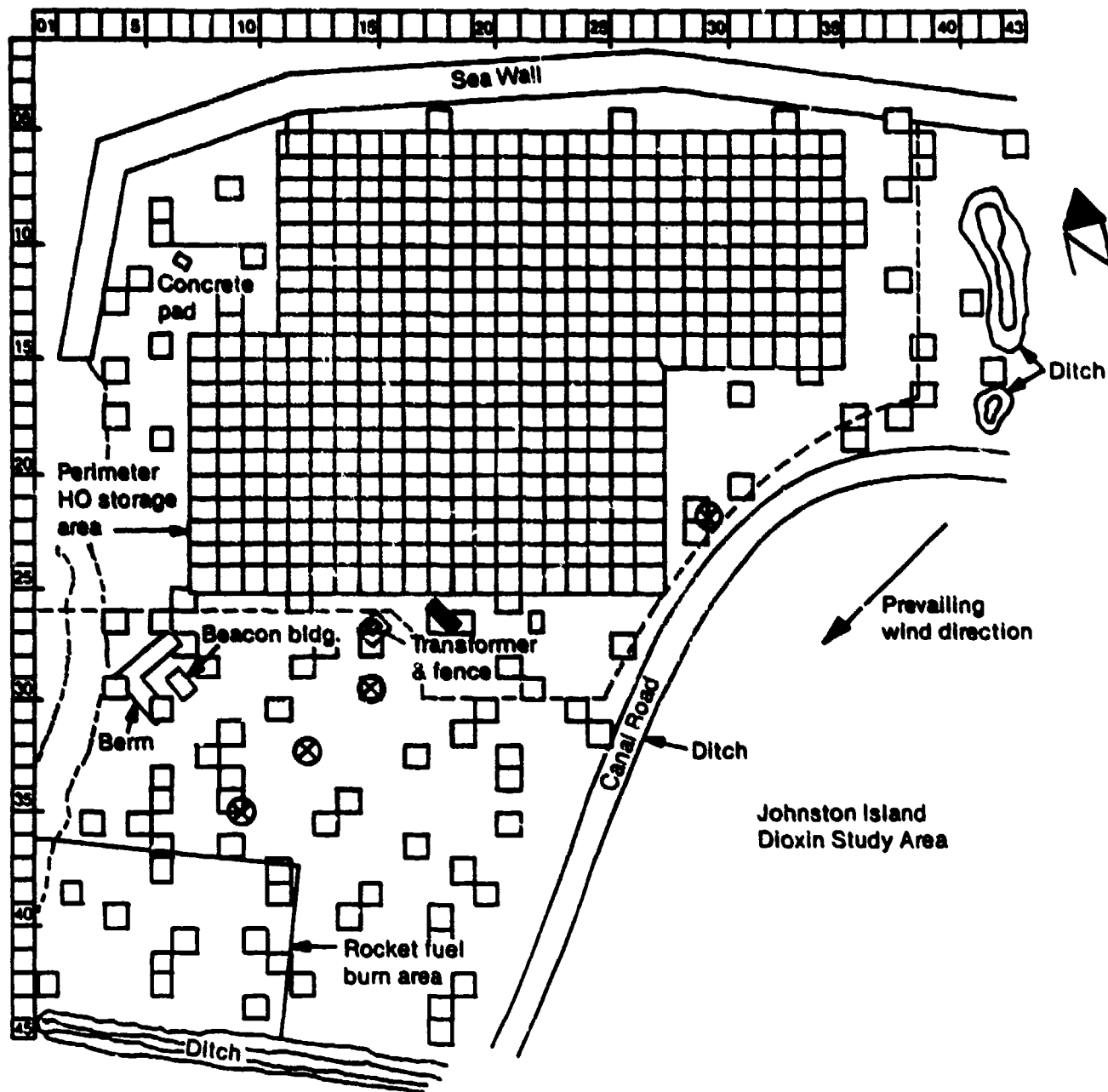


Figure 36. Layout of High-Volume Air Particulate Samplers.

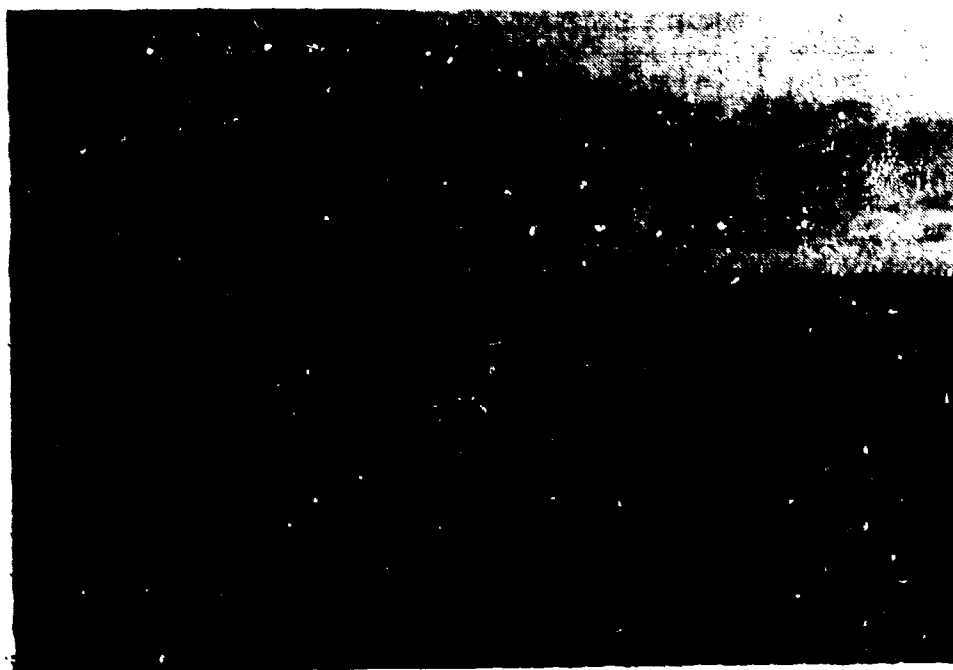


Figure 37. Upwind Control High-Volume Air Particulate Sampler (HV-D).



Figure 38. Downwind High-Volume Air Particulate Samplers (HV-C, F, E).

During Sample Set 2 and because of neutral air turbulence, Sampler HV-F was used to monitor for maximum impact from the site operations, and Sampler HV-E was a control to monitor conditions when the site was inactive. Samplers HV-C and -D were operated as in Sample Set 1.

During Sample Set 3, the HV-E sampler filter broke as it was being installed, causing the sampler to be taken out of service. Because the majority of site operations during this period were during the day, Sampler HV-F was placed in Sampler HV-E's position to monitor the maximum contaminant impact. Sample Set 3 then proceeded with only three samplers. No control sampling of natural migration during periods of nonsite activity was accomplished during Sample Set 3. Samplers HV-C and -D again functioned in the same manner as before.

All samplers were calibrated on Johnston Island on July 9, 1986, using a variable-resistance calibration orifice and a National Bureau of Standards calibration curve. All samplers were equipped with flow controllers, which maintained the sample flow rate as the filters loaded with particulates. The volume of air passing through each of the sampler filters was calculated by correcting the calibrated flow rate with the average temperature and barometric pressure encountered during the run. The average temperatures and pressures were determined from hourly onsite readings. These data may be found in Appendix O.

Table 6 lists the samples by set and the calculated air volume that passed through each sampler (Appendix O).

Each filter was left in its holder and placed in a plastic sealed bag. These samples were packed in the coolers with the material and gas samples previously discussed for shipment to ITAS.

TABLE 6. HIGH-VOLUME AMBIENT AIR SAMPLE SETS TAKEN

<u>Sample Set</u>	<u>Sampler</u>	<u>Migration Path Monitored</u>	<u>Sample Designation</u>	<u>Calculated Air Volume (m³)</u>
1	HV-C	Off island	JI-R1-12D	2476.4
	HV-D	Upwind control	JI-R1-12A	2716.9
	HV-E	Offsite control	JI-R1-12B	2716.9
	HV-F	Offsite control	JI-R1-12C	2564.8
2	HV-C	Off island	JI-R2-12D	3846.0
	HV-D	Upwind control	JI-R2-12A	4021.9
	HV-E	Offsite control	JI-R2-12B	4151.6
	HV-F	Offsite	JI-R2-12C	4032.7
3	HV-C	Off island	JI-R3-12D	4384.9
	HV-D	Upwind control	JI-R3-12A	2954.4
	HV-E	No sample taken	--	--
	HV-F	Offsite	JI-R3-12C	2852.2

SECTION V

RESULTS AND EVALUATION

A. ANALYTICAL RESULTS

Table 7 presents the process samples analyzed for test verification, including the Battelle dioxin/furan analysis of feedstock, treated soil, scrubber solvent, and treated solvent samples. Analyses of the volatile organic sampling train (VOST) samples were performed, and all 11 air filter samples were analyzed for 2,3,7,8-TCDD and total suspended particulates. This section presents the (1) ITAS methods/protocols, (2) Battelle methods/protocols, (3) data review, and (4) results.

1. Methods/Protocols (ITAS)

IT Analytical Services of Knoxville, Tennessee, performed the analyses. The methods and protocols were drawn from the EPA CLP procedures and are summarized below.

a. Dioxin/Furans

ITAS received 3 untreated soil samples, 6 treated soil samples, 8 Soltrol[®] samples, 3 carbon samples, 1 filter solid sample, 4 vent gas samples, 1 water sample, 8 ambient air filter samples, 6 industrial hygiene samples, and 14 wipe samples on July 28, 1986, for the analysis of both isomer-specific 2,3,7,8-TCDD and total dioxin and total dibenzofuran congeners from Cl₄ through Cl₆ (tetra, penta, hexa). The samples and a blank were spiked with an internal standard/surrogate mixture containing 50 ng of each of the compounds 2,3,7,8-TCDD-¹³C₁₂, P₅CDD-¹³C₁₂, and P₅CDF-¹³C₁₂, and 10 ng of 2,3,7,8-TCDD-³⁷Cl₄. The samples were extracted and cleaned up, using modifications of the EPA reference method described in Method 8280, "Analysis for Chlorinated Dibenzo-p-dioxins and Dibenzofurans," revised April 1983 (Reference 26). Separate method modifications of the basic were used for a diverse set of samples: soil,

TABLE 7. VERIFICATION SAMPLE ANALYSIS MATRIX PERFORMED FOR TD/UV
PHOTOLYSIS PROCESS TESTING AT JI

<u>Sample^{a,b}</u>	<u>Analytical Category</u>			
	<u>Dioxin/Furans</u>	<u>Organics</u>	<u>Inorganics</u>	<u>2,4-D/2,4,5-T</u>
<u>Feedstock</u>				
R1B-01	X	X	X	X
R1B-01B ^c	X	--	--	--
R2-01	X	--	--	--
R3-01	X	--	--	--
<u>Treated Soil</u>				
R1A-02	X	--	--	--
R1A-02B ^c	X	--	--	--
R1B-02B ^c	X	--	--	--
R2A-02	X	X	X	X
R2A-02A	X	--	--	--
R2B-02	X	--	--	--
R2-02B ^c	X	--	--	--
R3-02	X	X	X	X
R3-02A	-- ^d	--	--	--
R3-02B ^c	X	--	--	--
<u>Scrubber Solvent</u>				
R1-03	-- ^d	--	--	--
R1-03A	-- ^d	--	--	--
R1-03B	X	X	X	--
R1-03C	-- ^d	--	--	--
R2-03	X ^e	X	X	--
R3-03	X	X	X	--
<u>Treated Solvent</u>				
R1-04	X	X	X	X
R1-04A	-- ^d	--	--	--
R1-04B ^c	--	--	--	--
<u>Filtered Solids Composite</u>				
R1-03-06	-- ^d	--	--	--

TABLE 7. VERIFICATION SAMPLE ANALYSIS MATRIX PERFORMED FOR TD/UV
PHOTOLYSIS PROCESS TESTING AT JI (CONCLUDED)

<u>Sample^{a,b}</u>	<u>Analytical Category</u>			
	<u>Dioxin/Furans</u>	<u>Organics</u>	<u>Inorganics</u>	<u>2,4-D/2,4,5-1</u>
<u>Primary Adsorber</u>				
<u>Carbon</u>				
R2-09	-- ^d	--	--	--
R3-09	X	X	X	X
<u>Secondary Adsorber</u>				
<u>Carbon Composite</u>				
R1-03-10	X	X	X	X

a. Samples R1A-01, R1B-02, and R2B-02A, identified in Table 5, were not analyzed but served as backup samples.

b. Analysis performed by ITAS except where specifically noted as performed by Battelle. See footnotes c and e.

c. Samples sent to and analyzed by Battelle Columbus Laboratories.

d. Analyzed for 2,3,7,8-TCDD only.

e. Sample split with same field identification number used for each analytical laboratory.

carbon, water, Soltrol[®], industrial hygiene and ambient air filters, XAD-2 resin traps, and wipe samples. Extracts were analyzed by a high-resolution gas chromatograph/low-resolution mass spectrometer (HRGC/LRMS) operating in the selected ion monitoring mode for enhanced sensitivity. The column used for isomer-specific analysis was a 60-meter SP 2331 fused-silica column; whereas, the total isomer analysis used a 30-meter DB-5 fused-silica column.

Response factors for the isomer-specific analysis were obtained from a 5-point calibration curve run in triplicate; the response

factors for the total isomer analysis were based on a 3-point calibration curve. The analytical approach used by ITAS for the determination of total dioxins and furans is considered semiquantitative because of the lack of availability of all dioxin and furan isomer standards. A standard was injected at the beginning of each day to calculate response factors. The response factor solution contained the following isomer standards:

<u>Dioxins</u>	<u>Furans</u>
2,3,7,8-TCDD	2,3,7,8-TCDF
1,2,3,4-TCDD	--
1,2,3,7,8-P ₅ CDD	1,2,3,7,8-P ₅ CDF
1,2,3,4,7,8-H _x CDD	1,2,3,4,7,8-H _x CDF
2,3,7,8-TCDD- ¹³ C ₁₂	2,3,7,8-TCDF- ¹³ C ₁₂
2,3,7,8-TCDD- ³⁷ Cl ₄	--
1,2,3,7,8-P ₅ CDD- ¹³ C ₁₂	1,2,3,7,8-P ₅ CDF- ¹³ C ₁₂

To achieve adequate sensitivity, the samples were analyzed twice each: the first time for dioxins and the second time for furans. For isomer-specific analysis, the detection limit was calculated from 2.5 times the signal in the area of the elution of 2,3,7,8-TCDD-¹³C₁₂ (or 2,3,7,8-TCDF-¹³C₁₂) whenever the sample contained no detectable 2,3,7,8-TCDD (or 2,3,7,8-TCDF). For total congener analysis, the detection limit was calculated from 2.5 times the signal-to-noise ratio. Duplicates were analyzed for each of the following sample types: soil (R2A-02D), solvent (R1-04D), and carbon (R3-09D).

More detailed discussion on the procedures used is presented in Appendix R, Exhibit 1. Source information about the standards and reference materials for the dioxin and furan analyses is presented in Appendix R, Exhibit 2.

b. Volatile Organic Compound Analysis

The samples, including the VOST samples, were analyzed by purge and trap GC/MS in accordance with the EPA Statement of Work, July 1985 revision. This protocol is based on EPA Method 624 (Reference 27), which is the GC/MS method for analyzing purgeable organic priority pollutants in municipal and industrial wastewater. For further discussion on sample preparation and analysis procedures followed, see Appendix S, Exhibit 1. The solvent, VOST, and carbon samples presented some problems, which are briefly discussed in the following paragraphs.

The solvent was not soluble in methanol or water and had to be dispersed in polyethylene glycol (PEG) to get it into solution. The detection limits were affected by the small amounts of PEG that could be purged without foaming problems. The laboratory reran the samples later at much lower dilutions to answer questions concerning the presence of additional compounds. These analyses should be considered semiquantitative because of the time lag between sampling and analysis.

The original VOST analysis approach was to analyze the first set of tube pairs and then a second set if the sample concentration was above specified detection limits (25 ng/tube); otherwise, the remaining five pairs were to be combined into one analysis to increase analytical sensitivity. Two problems, arose that changed this approach:

- (1) Saturation levels of methylene chloride and Freon 113 were detected in the samples.
- (2) The trip blank contained levels of compounds similar to the samples although the field blanks did not.

The first sample problem was studied by separating the Tenax[®] and Tenax[®]/charcoal analysis for Sample JI-R2-11-06 to determine if the contamination was confined to only one of the tubes in the pair. The results showed high levels in both tubes. The second sample problem was

approached by analyzing additional tube pairs to find a set with low levels of contaminants that might be the trip blank. It was found that Sample JI-R2-11-10 appeared clean, suggesting that Trip Blank JI-R3-11-18 and Sample JI-R2-11-10 had switched sample identifications. The data reported in this package contain no assumptions to that effect and present the results with the original sample identifications.

The carbon samples exhibited high levels of volatile organics that affected surrogate recoveries. Several different dilution levels were analyzed to achieve the lowest possible detection limits. Matrix effects caused variable results between different runs of the same sample. In addition, a sample of the virgin carbon was introduced into the lab for analysis to find the source of the high levels of methylene chloride and Freon 113 seen in the VOST tubes and vent carbons. The results of the different runs have been combined on the organic analysis data sheets (Appendix S, Exhibit 2), and the most reliable numbers are selected at each dilution level.

c. Semivolatile Organic Compound Analysis

The sample extracts were analyzed for base/neutral and acid semivolatile organic compounds by fused silica capillary column (FSCC) -GC/MS procedures in accordance with the EPA CLP Statement of Work, July 1985 revision. This protocol is based on EPA Method 625 (Reference 27), which is the GC/MS method used for analyzing base/neutral and acid organic chemicals and pesticides listed as priority pollutants in municipal and industrial wastewater. For further discussion on sample preparation and analysis procedures followed, see Appendix S, Exhibit 1.

The solvent samples were originally analyzed by direct injection. However, the high levels of hydrocarbons that constituted the sample caused significant interference and decreased the level of confidence in the results. To decrease interferences and get more accurate results, particularly regarding the chlorophenolics, the sample was subjected to an acid/base partition and extraction/concentration. The acid

fraction was concentrated by a factor of 10:1, allowing a detection limit of 1 ppm to be achieved in the analysis. The base/neutral fraction could not be concentrated because of the hydrocarbon constituents discussed previously.

d. Organochlorine Pesticides and PCBs

The sample extracts were analyzed for organochlorine pesticides and PCBs by packed column GC electron capture detector (ECD) in accordance with the EPA CLP Statement of Work, July 1985 revision. This protocol is based on EPA Method 608 (Reference 27), which is the gas chromatography method for analyzing pesticides and PCBs in municipal and industrial wastewater. For further discussion on sample preparation and analysis procedures followed, see Appendix S, Exhibit 1.

e. Inorganic Analysis

The sample extracts were analyzed for metals and total cyanide on the PPL in accordance with the EPA CLP Statement of Work, July 1985 revision. This protocol provides for the determination of metals by inductively coupled argon plasma (ICP), graphite furnace atomic absorption (GFAA), and cold vapor atomic absorption technique for mercury. Alternatively, flame atomic absorption methods (AA) may be substituted for ICP. The CLP methods are based on methods in EPA-600/4-79-020 (Reference 28). For further discussion on sample preparation and analysis procedures followed, see Appendix S, Exhibit 1.

f. Compounds Indigenous to Herbicide Orange

The 2,4-D and 2,4,5-T compounds were considered a sufficient indication of remaining compounds indigenous to HO. The sample extracts were analyzed by GC/ECD in accordance with EPA Method 8150 (Reference 29), which is a gas chromatography procedure for chlorinated herbicides. For further discussion on sample preparation and analysis procedures followed, see Appendix S, Exhibit 1.

The initial untreated soil analytical results were not consistent with the expected results based on previous analysis of similar samples. The sample was reanalyzed to confirm the results. The second analysis was significantly higher, but still below the expected results. The laboratory conducted additional analysis to determine the cause of the variability. These procedures are discussed in Appendix S, Exhibit 3.

2. Methods/Protocols (Battelle)

The Battelle analyses were performed to determine specific levels for 2,3,7,8-TCDD and 2,3,7,8-TCDF and total isomer concentrations for tetra- through octachlorodibenzo-p-dioxin and tetra- through octachlorodibenzofuran in the following samples:

R1B-01B	untreated soil
R1A-02B	treated soil
R1B-02B	treated soil
R2-02B	treated soil
R3-02B	treated soil
R2-03	scrubber solvent
R1-04B	treated solvent

The purpose of the analyses was to compare results with the ITAS analytical data. The Battelle analytical methodologies for processing soil and solvent samples are presented in Appendix T. A brief description follows.

a. Soil Samples

All soil samples except R1B-01B, which was known to be relatively high in PCDD/PCDF, were spiked with 5.0 ng of the following internal standards: 2,3,7,8-TCDD- $^{13}\text{C}_{12}$, 2,3,7,8-TCDF- $^{13}\text{C}_{12}$, and Octa CDD- $^{13}\text{C}_{12}$. Sample R1B-01B was spiked with 50.0 ng of each of these standards. The samples were then Soxhlet-extracted for 18 hours using benzene. The final extracts were analyzed and quantified for PCDD/PCDF, using combined capillary column high-resolution gas

chromatography/high-resolution mass spectrometry (HRGC/HRMS). The column used a 60-meter DB-5 fused silica column operated in the splitless mode. The mass spectrometer was operated in the electron impact ionization mode.

Response factors for the 2,3,7,8-isomer-specific analysis were obtained from a 5-point calibration curve run in triplicate; whereas, the response factors for the total isomer analysis were obtained from a 3-point calibration curve run in triplicate. Chromatographic column performance was evaluated before any samples were analyzed to demonstrate proper resolution of the 2,3,7,8-TCDD isomer. Chromatographic "window" evaluation was also performed to ensure proper congener class separation. A standard was injected at the beginning of each day to calculate response factors and monitor any changes in the HRGC/HRMS. The response factor solution contained 5.0 ng of each of the following compounds:

<u>Dioxins</u>	<u>Furans</u>
2,3,7,8-TCDD	2,3,7,8-TCDF
1,2,3,7,8-P ₅ CDD	1,2,3,7,8-P ₅ CDF
1,2,3,4,7,8-H _x CDD	1,2,3,4,7,8-H _x CDF
2,3,7,8-TCDD- ¹³ C ₁₂	2,3,7,8-TCDF- ¹³ C ₁₂
1,2,3,4,-TCDD- ¹³ C ₁₂	

A duplicate and native spike of treated soil Sample R2-02B and a method blank were included in the analysis.

b. Solvent

The solvent sample known to have high levels of PCDD/PCDF, R2-03, was spiked with 41.7 ng of the internal standards. The remaining solvent samples were spiked with 5.0 ng of the internal standards. Each sample was dissolved in hexane, and the extracts were first passed through stacked acid and acid/base columns, and then passed through macro alumina

columns. After initial analysis showed high levels of interferences suspected to be PCBs, the solvent extracts were passed through Florisil^R columns for further cleanup. The final extracts were also analyzed and quantified for PCDD/PCDF using the capillary column HRGC/HRMS. Duplicates of Sample R1-04B and a method blank were included.

3. Data Review/Evaluation

The ITAS and Battelle data packages (References 30, 31, and 32), including the backup data, have been reviewed by the Chemical Sciences Group at EG&G Idaho. The ITAS summary in Reference 30 is included in this report as Appendix R, Exhibit 1. The significant parts of the ITAS summary report for Reference 31 are included as exhibits of Appendix S. The Battelle summary in Reference 32 is included in this report as Appendix T.

The review was conducted to verify that the prescribed analytical procedures were followed and data met limit conditions, where required. A summary of this review/evaluation follows. The detailed report is presented in Appendix U.

a. Dioxins and Furans (ITAS)

Two types of analyses were performed for the specified PCDDs and PCDFs: total isomer class content and 2,3,7,8-isomer specific. The review methodology was to evaluate all standard data in terms of applicable ion ratios, retention times, and signal-to-noise ratios to determine if the analytical results were correctly interpreted. The isomer-specific 2,3,7,8-TCDD data were examined and evaluated, using the criteria in the ITAS QA/QC plan. Applicable procedures are attached in Appendix U.

The overall set of data was examined. Spot checks were made to determine if ion ratios and calculations were correct and acceptable. No instances were found where differences were noted. Based on these checks, it was counterproductive to check each calculation.

Based on this review, it was concluded that the data were acceptable and that ITAS had followed the QA/QC guidelines of its QA/QC plan with minor exceptions. These exceptions do not affect the quality of the data.

b. Dioxins and Furans (Battelle)

Battelle Columbus Laboratories analyzed five soil samples, including one duplicate, and two solvent samples, including one duplicate for tetra- through hexachlorodibenzo-p-dioxins and tetra- through hexa-chloro-dibenzofurans. These samples were split to compare results with the ITAS data. The analytical data submitted by Battelle were reviewed using the QA/QC criteria outlined in its report (Reference 32, see also applicable procedures attached in Appendix T). The data were found to be in general compliance with the QA/QC criteria. Therefore, the results are valid from the standpoint of meeting the appropriate QA/QC criteria.

There is reasonable agreement between the ITAS and Battelle results for the split samples. The major discrepancy is in the isomer class data for P₅CDD. The Battelle results for P₅CDD are considerably higher than the ITAS results. The results reported by each laboratory are analytically correct; no errors were found in identification of peaks or quantitation of results. Possible reasons contributing to the differences are that Battelle performed the analysis by high-resolution MS; whereas, ITAS used LRMS. The HRMS method used is 100-1000 times more sensitive than the LRMS method. Also, Battelle used an internal P₅CDD-¹³C₁₂ standard for quantitating the results; whereas, ITAS did not spike the samples with a similar standard. With the use of the labeled internal standard recovery losses are corrected for automatically. Because there are no standard reference materials except for 2,3,7,8-TCDD, it is possible that Battelle and ITAS used different standards to quantitate the analyses.

c. Volatile Organic Components

ITAS analyzed various soil, carbon, and solvent samples and VOST tubes for volatile organic components. The review methodology of the data package (Reference 31) followed the requirements specified in the CLP protocol, July 1985 revision.

Problems were encountered with the VOST tube analyses. Indications are that methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), used as equipment decontamination solvents, leaked from their containers, contaminating the carbon used in the adsorbers. These chemicals were packed and shipped with the carbon so they were in close contact for approximately 10 months during shipment and extended storage at JI while awaiting the EPA permit approval for the test. The result of this contamination was that the quantitation mass was saturated for chloromethane for all VOST tube samples, which biased the results for all other components. Therefore, average concentrations for each detected priority pollutant had to be calculated and presented in the report.

The CLP protocol states that, for volatile organic analysis, the maximum holding time for liquid samples is 7 days and for solid samples, 10 days. The protocol further states that all samples are to be protected from light and stored at 40 °F until extracted. The holding time for solvent samples was slightly exceeded (1 day) for Samples R2-03, R3-03, and R1-04. The holding time for some of the VOST tube samples was also exceeded. Samples R2-11-07 and R3-11-07 were analyzed 17 days after receipt; and Samples R2-11-08, R2-11-10, and R3-11-08 were analyzed 23 days after receipt. The holding time on these VOST tube samples was due to the problems encountered with the methylene chloride and Freon 113 contamination. The data report did not indicate the conditions of sample storage. A review of the data package showed that all standards and instrument calibrations were performed according to the protocol.

Based on the total review, the data for volatile organic components are considered valid, with the exception of the VOST tube samples and the three liquid samples noted above. Even in these cases, the data can probably be used as a guide in the evaluation of the TD/UV photolysis.

d. Semivolatile Organic Components (Base/Neutral/Acids)

ITAS analyzed various soil, carbon, and solvent samples for semivolatile (base/neutral/acid) organic components. The review methodology of the data package (Reference 31) followed the requirements specified in the CLP protocol, July 1985 revision.

All extractions and extract analyses were performed within the timeframe specified in the protocol. All other aspects of the protocol were followed in a complete and timely manner. The data for semivolatile organic compounds are considered valid.

e. Organochlorine Pesticides and PCBs

Soil, carbon, and solvent samples were analyzed by ITAS for organochlorine pesticides and PCBs. The review methodology of the data package (Reference 31) followed the requirements specified in the CLP protocol, July 1985 revision.

As in the case of the semivolatile compounds, the analytical protocol was followed in a complete and timely manner. Thus, the data are considered valid.

f. Inorganics

Soil, carbon, and solvent samples were analyzed by ITAS for inorganics, including total cyanide. The review methodology of the data package (Reference 31) followed the requirements specified in the CLP

protocol, July 1985 revision. Based on a review of the raw data, all standards and instrument calibrations required by the protocol were followed. The inorganic data are considered valid.

g. Herbicide Orange Analysis

ITAS analyzed soil, carbon, and solvent samples for components indigenous to HO. The review methodology of the data package (Reference 31 and Addendum 1 to the reference) followed the requirements specified in EPA Method 8150 (Reference 29).

All requirements of the method were followed. However, problems were encountered with Sample R1B-01, which was soil feedstock. Apparent matrix problems interfered with the methylation of the 2,4-D and 2,4,5-T components. Thus, results on duplicate 50-gram aliquot samples could not be replicated. By reducing sample size to 1-gram aliquots and following the methylation procedure, increased concentrations and better reproducibility of results were obtained:

<u>Component</u>	<u>50-gram Sample</u>	<u>1-gram Sample</u>	
	<u>R1B-01</u>	<u>R1B-01</u>	<u>R1B-01 duplicate</u>
2,4-D, ppm	22	140	110
2,4,5-T, ppm	61	420	300

Because spike recoveries were still low, the R1B-01 data cannot be validated; however, the data may be used as a general indication of HO presence. For further discussion on this problem, see Addendum 1 to Reference 31 (included in Appendix S, Exhibit 3, for reader convenience).

Apparently, problems were not encountered with the other samples. Based on the above, the data for HO components can be considered valid, with the exception of the data obtained on Sample R1B-01.

b. Conclusions

All ITAS and Battelle dioxin/furan analytical results are valid for use in evaluating the TD/UV photolysis technology on treating JI soil. All ITAS semivolatile organic component, organochlorine pesticide, PCB, and inorganic analytical results are also valid for evaluation use. Because of excessive holding times compared to protocol requirements, the VOST sample data could not be validated. The volatile organic component data for three solvent samples (R2-03, R3-03, and R1-04) could not be technically validated because holding times exceeded the protocol requirement by 1 day. All other volatile organic component analysis results are valid. Also, all HO component analytical results are valid except for untreated soil Sample R1B-01. Data that could not be validated can be used to evaluate the effectiveness of the TD/UV photolysis process.

4. Analytical Results

The analytical results are presented in the following order: desorption test feedstock and treated soil, UV photolysis scrubber solvent and treated solvent, filtered solids from the scrubber solvent, filter materials in the desorption test gas exhaust stream, VOST tube, and ambient air filters. Where appropriate, data have been combined in tables for comparison of results. Significant ITAS and Battelle data sheets are included in Appendices R and S, and T, respectively, for reference. Detailed data sheets, graphs, procedures, and quality assurance records are included in the data packages submitted by ITAS and Battelle to EG&G Idaho (References 30, 31, and 32).

a. Soil Feedstock

The PCDD and PCDF results for the soil feedstock used in the four desorption test runs are shown in Tables 8, 9, and 10. Data for Runs 2 and 2A are combined in Table 9 because the same feedstock lot was used. Table 8 includes the Battelle results for its feedstock sample from Run 1. The concentrations of 2,3,7,8-TCDD and total TCDD dominated all

TABLE 8. POLYCHLORODIBENZO-P-DIOXIN AND POLYCHLORODIBENZOFURAN CONCENTRATIONS IN DESORPTION TEST RUN : SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

PCDD/PCDF	Concentration (ppb)			
	Soil Feedstock ^{a,c} (ITAS)	Soil Feedstock ^{b,d} (Battelle)	Treated Soil ^{a,e} (ITAS)	Treated Soil ^{b,f} (Battelle)
<u>Dioxins</u>				
Total TCDD	46.1	35.5	<0.079 ^h	<0.014 ^h
2,3,7,8-TCDD	57.0	33.8	<0.094	<0.014
Total P ₅ CDD	<0.17 ^h	15.0	<0.010	<0.050
Total H ₄ CDD	<0.34	0.91	<0.0083	<0.017
<u>Furans</u>				
Total TCDF	<0.29	4.36	<0.027	<0.035
2,3,7,8-TCDF	<0.17	0.36	<0.035	<0.035
Total P ₅ CDF	<0.16	1.56	<0.017	<0.014
Total H ₄ CDF	<0.26	0.05	<0.18	<0.004 ^h

a. See Appendix R, Exhibit 1, for ITAS data sheets.

b. See Appendix T for Battelle data sheets.

c. Sample ID: R1B-01; ITAS Lab No. J3509.

d. Sample ID: R1B-01B; no Battelle lab number.

e. Sample ID: R1A-02; ITAS Lab No. J3506.

f. Sample ID: R1A-02B; no Battelle lab number.

g. Sample ID: R1B-02B; no Battelle lab number.

h. Not detected. Detection limit value shown.

TABLE 9. POLYCHLORODIBENZO-P-DIOXIN AND POLYCHLORODIBENZOFURAN CONCENTRATIONS IN DESORPTION TEST RUN 2 SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

PCDD/PCDF	Concentration (ppb)					
	Soil Feedstock ^{a,c} (ITAS)	Treated Soil ^{a,d} (ITAS)	Treated Soil ^{a,e} (ITAS)	Treated Soil ^{a,f} (ITAS)	Treated Soil ^{b,h} (Battelle)	Treated Soil ^{b,i} (Battelle)
<u>Dioxins</u>						
Total TCDD	41.1	<0.012 ^j	<0.012 ^j	<0.032 ^j	<0.0044 ^j	<0.004 ^j
2,3,7,8-TCDD	48.1	<0.084	<0.056	<0.047	<0.054	<0.004
Total P ₅ CDD	0.052	<0.035	<0.14	<0.011	<0.027	<0.008
Total H _x CDD	<0.28 ^j	<0.12	<0.0038	<0.18	<0.012	<0.004
<u>Furans</u>						
Total TCDF	0.55	<0.015	<0.10	<0.0023	<0.0082	<0.002
2,3,7,8-TCDF	0.29	<0.071	<0.058	<0.026	<0.024	<0.002
Total P ₅ CDF	0.069	<0.0081	<0.051	<0.0051	<0.0055	<0.003
Total H _x CDF	<0.059	<0.11	<0.38	<0.039	<0.038	<0.002
a. See Appendix K, Exhibit 1, for ITAS data sheets.						
b. See Appendix T for Battelle data sheets.						
c. Sample ID: R2-01; ITAS Lab No. J3514.						
d. Sample ID: R2A-02; ITAS Lab No. J3512.						
e. Sample ID: R2A-02 duplicate; ITAS Lab No. J3512D.						
f. Sample ID: R2A-02A; ITAS Lab No. J3513.						
g. Sample ID: R2B-02; ITAS Lab No. J3527.						
h. Sample ID: R2-02B; no Battelle lab number.						
i. Sample ID: R2-02B duplicate; no Battelle lab number.						
j. Not detected. Detection limit value shown.						

TABLE 10. POLYCHLORODIBENZO-P-DIOXIN AND POLYCHLORODIBENZOFURAN CONCENTRATIONS IN DESORPTION TEST RUN 3 SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

PCDD/PCDF	Concentration (ppb)		
	Soil Feedstock ^{a,c} (ITAS)	Treated Soil ^{a,d} (ITAS)	Treated Soil ^{b,f} (Battelle)
<u>Dioxins</u>			
Total TCDD	48.0	0.20	NA ^g
2,3,7,8-TCDD	56.0	0.23	0.12
Total P ₅ CDD	<0.035 ^h	<0.069 ^h	0.29
Total H ₄ CDD	<0.62	<0.24	0.10
<u>Furans</u>			
Total TCDF	<0.12	<0.011	0.24
2,3,7,8-TCDF	<0.16	<0.066	0.03
Total P ₅ CDF	<0.24	<0.025	0.10
Total H ₄ CDF	<0.50	<0.0065	<0.003 ^h

a. See Appendix R, Exhibit 1 for ITAS data sheets.

b. See Appendix T for Battelle data sheets.

c. Sample ID: R3-01; ITAS Lab No. J3529.

d. Sample ID: R3-02; ITAS Lab No. J3526.

e. Sample ID: R3-02A; no ITAS lab number.

f. Sample ID: R3-02B; no Battelle lab number.

g. NA = Not analyzed.

h. Not detected. Detection limit value shown.

other PCDD/PCDF congeners analyzed. Based on ITAS data, the 2,3,7,8-TCDD averaged 54 ppb and ranged from 48.1 to 57.0 ppb, which shows consistency between the three lots of feedstock. The total TCDD averaged 45 ppb and ranged from 41.1 to 48.0 ppb, which indicates an analytical bias between the isomer specific analysis and the congener analysis.

The Battelle results for the Run 1 sample show lower concentrations for 2,3,7,8-TCDD (33.8 ppb) and total TCDD (35.5) and in a more consistent relationship. The ITAS data show no other congeners detected above 1 ppb. This is in variance with the Battelle results, which showed P₅CDD at 15 ppb, TCDF at 4.36 ppb, and P₅CDF at 1.56 ppb. The possible reasons for this difference are discussed in Section V.A.3.b.

The analytical results for volatile organic components for the one feedstock sample analyzed (R1B-01) are shown in Table 11. No volatiles on the PPL (Appendix I) were detected, and DLVs were well below the 1 ppm requirement.

The analytical results for semivolatile organic components for feedstock Sample R1B-01 are shown in Table 12. No semivolatiles on the PPL (Appendix J) were detected. DLVs were below the 1.0 ppm requirements, except for four components which had DLVs of 1.6 ppm.

The analytical results for organochlorine pesticides and PCBs in feedstock Sample R1B-01 are presented in Table 13. Only 4,4'-DDT was detected (0.044 ppm), and this is well below the 1 ppm detection objective. For all other components on the PPL (Appendix I), the DLVs were well below the 1 ppm requirement.

The analytical results for inorganics in feedstock Sample R1B-01 are presented in Table 14. Zinc has the highest concentration at 46 ppm. Other elements detected in excess of 1 ppm were copper (10 ppm), lead (9.2 ppm), and chromium (9.0 ppm). Detection limits met or were less than the required 1 ppm for the other PPL inorganics/cyanide except for nickel, which had a DLV of 2 ppm. Although not on the PPL, barium was analyzed for and was not detected at a DLV of

TABLE 11. VOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

Component	Concentration ^a (ppm)		
	Run 1 Soil Feedstock ^b	Run 2 Treated Soil ^c	Run 3 Treated Soil ^d
Acrolein	<0.010 ^e	<0.050 ^e	<0.050 ^e
Acrylonitrile	<0.010	<0.050	<0.050
Benzene	<0.005	0.70	0.77
Carbon Tetrachloromethane (carbon tetrachloride)	<0.005	<0.025	<0.025
Chlorobenzene	<0.005	<0.025	<0.025
1,2-Dichloroethane	<0.005	<0.025	<0.025
1,1,1-Trichloroethane	<0.005	<0.025	<0.025
1,1-Dichloroethane	<0.005	<0.025	<0.025
1,1,2-Trichloroethane	<0.005	<0.025	<0.025
1,1,2,2-Tetrachloroethane	<0.005	<0.025	<0.025
Chloroethane (ethyl chloride)	<0.010	<0.050	<0.050
2-Chloroethyl vinyl ether	<0.010	<0.050	<0.050
Trichloromethane (chloroform)	<0.005	<0.025	<0.025
1,1-Dichloroethene	<0.005	<0.025	<0.025
Trans-1,2-dichloroethene	<0.005	<0.025	<0.025
1,2-Dichloropropane	<0.005	<0.025	<0.025
1,3-Dichloropropane	<0.005	<0.025	<0.025
Ethyl benzene	<0.005	<0.170	<0.043
Dichloromethane (methylene chloride)	0.0069 ^f	0.0036 ^g	0.040 ^g
Chloromethane (methyl chloride)	<0.010	<0.050	<0.050
Bromomethane (methyl bromide)	<0.010	<0.050	<0.050
Tribromomethane (bromoform)	<0.005	<0.025	<0.025
Bromodichloromethane	<0.005	<0.025	<0.025
Dibromochloromethane	<0.005	<0.025	<0.025
Tetrachloroethene	<0.005	<0.025	<0.025

TABLE 11. VOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST SOIL FEEDSTOCK AND TREATED SOIL SAMPLES (CONCLUDED)

<u>Component</u>	<u>Concentration^a (ppm)</u>		
	<u>Run 1 Soil Feedstock^b</u>	<u>Run 2 Treated Soil^c</u>	<u>Run 3 Treated Soil^d</u>
Toluene	<0.005	1.10	0.64
Trichloroethane	<0.005	<0.025	<0.025
Chloroethene (vinyl chloride)	<0.010	<0.050	<0.050

a. See Appendix S, Exhibit 2, for ITAS data sheets.

b. Sample ID: R1B-01; ITAS Lab No. AA0645.

c. Sample ID: R2A-02; ITAS Lab No. AA0646.

d. Sample ID: R3-02; ITAS Lab No. AA0648.

e. Not detected. Detection limit value shown.

f. Indicates an estimated value.

g. Analyte was found in the blank as well as the sample. Indicates possible blank contamination.

20 ppm. Barium is an element listed in the EP Toxicity test (40 CFR 261.24).

The total analysis for 2,4-D and 2,4,5-T in feedstock Sample R1B-01 clearly shows the HO contamination even though there were difficulties encountered in the analysis (see procedures discussion in Paragraph V.A.1.f). Concentrations are shown below.

<u>Sample</u>	<u>Concentration (ppm)</u>	
	<u>2,4-D</u>	<u>2,4,5-T</u>
R1B-01	140	420
R1B-01 duplicate	110	300

TABLE 12. SEMIVOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

Component ^b	Concentration ^a (ppm)		
	Run 1 Soil Feedstock ^c	Run 2 Treated Soil ^d	Run 3 Treated Soil ^e
<u>Acid Type</u>			
2,4,6-Trichlorophenol	<0.33 ^f	<0.33 ^f	<0.33 ^f
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	<0.33	<0.33	<0.33
2-Chlorophenol	<0.33	<0.33	<0.33
2,4-Dichlorophenol	<0.13 ^g	<0.33	<0.33
2,4-Dimethylphenol	<0.33	<0.33	<0.33
2-Nitrophenol	<0.33	<0.33	<0.33
4-Nitrophenol	<1.60	<1.60	<1.60
2,4-Dinitrophenol	<1.60	<1.60	<1.60
2-Methyl-4,6-dinitrophenol (4,6-Dinitro-o-cresol)	<1.60	<1.60	<1.60
Pentachlorophenol	<1.60	<1.60	<1.60
Phenol	<0.33	<0.33	<0.33
<u>Base/Neutral Type</u>			
Acenaphthene	<0.33	<0.33	<0.33
1,2,4-Trichlorobenzene	<0.33	<0.33	<0.33
Hexachlorobenzene	<0.33	<0.33	<0.33
Hexachloroethane	<0.33	<0.33	<0.33
bis (2-Chloroethyl) ether	<0.33	<0.33	<0.33
2-Chloronaphthalene	<0.33	<0.33	<0.33
1,2-Dichlorobenzene	<0.33	<0.33	<0.33
1,3-Dichlorobenzene	<0.33	<0.33	<0.33
1,4-Dichlorobenzene	<0.33	<0.33	<0.33
3,3'-Dichlorobenzidine	<0.66	<0.66	<0.66
2,4-Dinitrotoluene	<0.33	<0.33	<0.33
2,6-Dinitrotoluene	<0.33	<0.33	<0.33
Fluoranthene	<0.33	0.04 ^g	<0.33
4-Chlorophenyl phenyl ether	<0.33	<0.33	<0.33
4-Bromophenyl phenyl ether	<0.33	<0.33	<0.33

TABLE 12. SEMIVOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST SOIL FEEDSTOCK AND TREATED SOIL SAMPLES (CONTINUED)

Component ^b	Concentration ^a (ppm)		
	Run 1 Soil Feedstock ^c	Run 2 Treated Soil ^d	Run 3 Treated Soil ^e
bis (2-Chloroisopropyl) ether			
bis (2-Chloroethoxy) methane	<0.33	<0.33	<0.33
Hexachlorobutadiene	<0.33	<0.33	<0.33
Hexachlorocyclopentadiene	<0.33	<0.33	<0.33
Isophorone	<0.33	<0.33	<0.33
Naphthalene	<0.33	0.26 ^g	0.21 ^g
Nitrobenzene	<0.33	<0.33	<0.33
Diphenyl nitrosamine (N-nitrosodiphenylamine)	<0.33	<0.33	<0.24 ^g
Di-n-propyl nitrosamine (N-Nitrosodi-n- propylamine)	<0.33	<0.33	<0.33
bis (2-Ethylhexyl) phthalate	0.17 ^g	<0.33	<0.33
Benzyl butyl phthalate	<0.33	0.06 ^g	0.06 ^{g,h}
Di-n-butyl phthalate	0.23 ^{g,h}	0.18 ^{g,h}	0.22 ^{g,h}
Di-n-octyl phthalate	<0.33	<0.33	<0.33
Diethyl phthalate	0.071 ^g	<0.045 ^g	0.056 ^g
Dimethyl phthalate	<0.33	<0.33	<0.33
Benzo(a)anthracene	<0.33	<0.33	<0.33
Benzo(a)pyrene	<0.33	<0.33	<0.33
Benzo(b)fluoranthene	<0.33	<0.33	<0.33
Benzo(k)fluoranthene	<0.33	<0.33	<0.33
Chrysene	<0.33	<0.33	<0.33
Acenaphthylene	<0.33	<0.33	<0.33
Anthracene	<0.33	<0.33	<0.33
Benzo(g,h,i)perylene	<0.33	<0.33	<0.33
Fluorene	<0.33	<0.33	<0.33

TABLE 12. SEMIVOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST SOIL, FEEDSTOCK AND TREATED SOIL SAMPLES (CONCLUDED)

Component ^b	Concentration ^a (ppm)		
	Run 1 Soil Feedstock ^c	Run 2 Treated Soil ^d	Run 3 Treated Soil ^e
Phenanthrene	<0.33	<0.07 ^g	<0.066 ^g
Dibenzo(a,h)anthracene	<0.33	<0.33	<0.33
Indeno(1,2,3-c,d)pyrene	<0.33	<0.33	<0.33
Pyrene	<0.33	<0.04 ^g	<0.33

a. See Appendix S, Exhibit 2, for ITAS data sheets.

b. Analysis not made for benzidine dimethyl nitrosamine (N-nitrosodimethylamine) as listed in the modified PPL (see Appendix I).

c. Sample ID: R1B-01; ITAS Lab No. AA0645.

d. Sample ID: R2A-02; ITAS Lab No. AA0646.

e. Sample ID: R3-02; ITAS Lab No. AA0648.

f. Not detected. Detection limit value shown.

g. Indicates an estimated value.

h. Analyte was found in the blank as well as the sample. Indicates possible blank contamination.

Other HO constituents such as the semivolatiles 2-chlorophenol, 2,4-dichlorophenol, 2,4,5-trichlorophenol, or 2,4,6-trichlorophenol were either detected at less than 1 ppm or not detected, with DLVs less than 1 ppm.

b. Treated Soil

Tables 8, 9, and 10 compare the PCDD and PCDF results for the treated soil with the results of the feedstock for the three test runs, respectively. Both ITAS and Battelle data are shown for each test run.

TABLE 13. ORGANOCHLORINE PESTICIDE AND PCB CONCENTRATIONS IN DESORPTION TEST SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

Component	Concentration ^a (ppm)		
	Run 1 Soil Feedstock ^b	Run 2 Treated Soil ^c	Run 3 Treated Soil ^d
Aldrin	<0.0085 ^e	<0.0081 ^e	<0.008 ^e
Alpha-BHC	<0.0085	<0.0081	<0.008
Beta-BHC	<0.0085	<0.0081	<0.008
Gamma-BHC (Lindane)	<0.0085	<0.0081	<0.008
Delta-BHC	<0.0085	<0.0081	<0.008
Chlordane	<0.085	<0.081	<0.080
4,4'-DDD	<0.017	<0.016	<0.016
4,4'-DDE	<0.017	<0.016	<0.016
4,4'-DDT	<0.044	<0.016	<0.016
Dieldrin	<0.017	<0.016	<0.016
Endosulfan I	<0.0085	<0.0081	<0.008
Endosulfan II	<0.017	<0.016	<0.016
Endosulfan sulfate	<0.031	<0.016	<0.016
Endrin	<0.017	<0.016	<0.016
Endrin aldehyde	<0.017	<0.016	<0.016
Heptachlor	<0.0085	<0.0081	<0.008
Heptachlor epoxide	<0.0085	<0.0081	<0.008
Toxaphene	<0.017	<0.160	<0.160
PCB 1016	<0.085	<0.081	<0.080
PCB 1221	<0.085	<0.081	<0.080
PCB 1232	<0.085	<0.081	<0.080
PCB 1242	<0.085	<0.081	<0.080
PCB 1248	<0.085	<0.081	<0.080
PCB 1254	<0.170	<0.160	<0.160
PCB-1260	<0.170	<0.160	<0.160

a. See Appendix S, Exhibit 2, for ITAS data sheets.

b. Sample ID: R1B-01; ITAS Lab No. AA0645.

c. Sample ID: R2A-02; ITAS Lab No. AA0646.

d. Sample ID: R3-02; ITAS Lab No. AA0648.

e. Not detected. Detection limit value shown.

TABLE 14. INORGANIC CONCENTRATIONS IN DESORPTION TEST SOIL FEEDSTOCK AND TREATED SOIL SAMPLES

Component	Concentration ^a (ppm)		
	Run 1 Soil Feedstock ^b	Run 2 Treated Soil ^c	Run 3 Treated Soil ^d
Antimony	<0.6 ^f	<0.5 ^f	<0.6 ^f
Arsenic	0.98	0.96	1.3
Barium ^e	<20.0	85	51
Beryllium	<0.4	<0.4	<0.4
Cadmium	<0.2	<0.2	<0.2
Chromium	9.0 ^g	7.7 ^g	7.2 ^g
Copper	10	11	11
Lead	9.2 ^h	7.7 ^h	9.8 ^h
Mercury	0.24 ^{g,h}	<0.02 ^{g,h}	<0.02 ^{g,h}
Nickel	<2 ^g	<2 ^g	<2 ^g
Selenium	<1	<1	<1
Silver	<1	<0.8	<0.4
Thallium	<1	<0.6	<0.6
Zinc	46 ^{g,h,i}	110 ^{g,h,i}	61 ^{g,h,i}
Total cyanide	<0.5	4.3	3.5

a. See Appendix S, Exhibit 4, for ITAS data sheets.

b. Sample ID: R1B-01; ITAS Lab No. AA0645.

c. Sample ID: R2A-02; ITAS Lab No. AA0646.

d. Sample ID: R3-02; ITAS Lab No. AA0648.

e. Barium is not on the PPL (Appendix I), but is an element listed in the EP Toxicity test per 40 CFR 261.24.

f. Not detected. Detection limit value shown.

g. Duplicate analysis was not within control limits.

h. Positive values were obtained in the sample preparation blank that were close to or at the instrument detection limit.

i. Spike recovery was not within control limits.

For Run 1, which operated at 1049 °F and 99 lb/hr feedstock feed rate, the ITAS sample data (R1A-02) and the Battelle sample laboratory duplicate data (R1B-02B) showed no detectable PCDD or PCDF, with DLVs of 0.18 ppb or less. The Battelle data for Sample R1A-02B showed detectable levels; however, the amount of any one congener was less than 0.1 ppb.

For the two runs of Test 2, which were operated at 1094 °F and 193.6 lb/hr for Run 2 and 1022 °F and 209 lb/hr for Run 2A, both ITAS and Battelle data show no detectable PCDD/PCDF, with DLVs of 0.38 ppb or less. For Run 3, which operated at 1031 °F and 50.6 lb/hr, the ITAS and Battelle analytical results show detectable PCDD/PCDF. For example, the ITAS data for Sample R3-02 exhibited 0.23 ppb for 2,3,7,8-TCDD specific analysis and 0.20 ppb for the TCDD congener analysis. No congeners were detected, with DLVs being 0.24 ppb or less. The 2,3,7,8-TCDD specific analysis for ITAS field duplicate Sample R3-02A showed 0.24 ppb, which agrees with the R3-02 result. However, the Battelle data showed detectable amounts of all PCDD/PCDF congeners except H_xCDF. The P₅CDD congener exhibited the highest magnitude (0.29 ppb).

Eighty percent of the ITAS congener results shown as not detectable for the test runs had DLVs at 0.1 ppb or less. The highest was 0.38 ppb. In all cases, the Battelle congener results shown as not detectable had DLVs at 0.1 ppb or less. As shown in Table 15, the concentration sum of the six PCDD/PCDF congeners for each treated soil sample for all test runs is less than the 1.0 ppb concentration goal that was a project objective. Where the ITAS analysis showed the isomer specific results higher than the congener results, the higher results were used in the sum.

Table 11 shows the volatile organic analytical results for treated soil samples from Runs 2 and 3 (Samples R2A-02 and R3-02). Because the feedstocks for these runs were not analyzed for volatiles, the treated soil results are compared with feedstock sample results for Run 1, which can be used as a guide. Small amounts of toluene (1.10 ppm, 0.64 ppm) and

TABLE 15. SUM OF PCDD/PCDR TETRA-, PENTA-, AND HEXA-CONGENER CONCENTRATIONS FOR TREATED SOIL SAMPLES

<u>Test Run</u>	<u>Sample</u>	<u>Congener Concentration Sum</u> <u>(ppt)</u>	
		<u>ITAS</u>	<u>Battelle</u>
1	R1A-02	0.344	--
	R1A-02B	--	0.194
	R1A-02B duplicate	--	0.136
2,2A	R2A-02	0.428	--
	R2A-02 duplicate	0.731	--
	R2A-02A	0.308	--
	R2B-02	0.161	--
	R2-02B	--	0.037
	R2-02B duplicate	--	0.023
3	R3-02	0.637	--
	R3-02B	--	0.883

benzene (0.70 ppm, 0.77 ppm) were detected in the treated soil for Runs 2 and 3; whereas, these components were not detected in the Run 1 feedstock sample, with DLVs at 0.005 ppm.

Table 12 shows the semivolatile organic analytical results for treated soil samples from Runs 2 and 3 (Samples R2A-02 and R3-02). No components were detected at 1 ppm or more. The results appear very consistent with the feedstock results for the Run 1 sample (R1B-01), including the four DLVs that exceeded the 1.0 ppm requirement at 1.6 ppm.

Table 13 shows the organochlorine pesticide and PCB analytical results for treated soil samples from Runs 2 and 3 (Samples R2A-02 and R3-02). No components were detected, and DLVs were well below the 1.0 ppm requirement, with the highest at 0.16 ppm. Data were consistent with the feedstock results for Sample R1B-01.

Table 14 shows the inorganic analytical results for treated samples from Runs 2 and 3 (Samples R2A-02 and R3-02). Except for two anomalies, the data are consistent with the feedstock results for Sample R1B-01. One anomaly is that barium concentrations of 85 ppm and

51 ppm are shown for the two treated soil samples; whereas, the feedstock sample for Run 1 (R1B-01) shows none detected at a DLV of 20 ppm. The other anomaly relates to total cyanide, which was observed at 4.3 ppm and 3.5 ppm in the two treated soil samples. In the feedstock sample, total cyanide was not detected at a DLV of 0.5 ppm.

The treated soil samples for Runs 2 and 3 (Samples R2A-02 and R3-02) showed no detectable amounts of the HO constituents 2,4-D or 2,4,5-T, with DLVs at 0.010 ppm (Table 16). This reduction is substantial compared to the feedstock results (Sample R1B-01), which are also shown in Table 16.

c. Scrubber Solvent

Table 17 shows the PCDD and PCDF results for the untreated scrubber solvent used in the three desorption test runs. The sample for Run 1 (R1-03) was analyzed only for 2,3,7,8-TCDD and exhibited a concentration of 210 ppb. The same solvent was used in Run 2/2A, with

TABLE 16. CONCENTRATIONS OF HO CONSTITUENTS 2,4-D AND 2,4,5-T IN DESORPTION TEST FEEDSTOCK AND TREATED SOIL SAMPLES

Sample ID	ITAS Lab Number	Concentration (ppm)	
		2,4-D	2,4,5-T
<u>Feedstock</u>			
R1B-01	AA0645	140 ^a	420 ^a
R1B-01 (duplicate)	AA0645 ^d	110 ^a	300 ^a
<u>Treated Soil</u>			
R2A-02	AA0646	<0.010 ^b	<0.010 ^b
R2A-02 (duplicate)	AA0646 ^d	<0.010 ^b	<0.010 ^b
R3-02	AA0648	<0.010 ^b	<0.010 ^b

a. See Appendix S, Exhibit 3, for ITAS data sheets.

b. See Appendix S, Exhibit 2, for ITAS data sheets.

TABLE 17. POLYCHLORODIBENZO-P-DIOXIN AND POLYCHLORODIBENZOFURAN CONCENTRATIONS IN UV PHOTOLYSIS TEST UNTREATED AND TREATED SOLVENT SAMPLES

PCDD/PCDF	Concentration (ppb)							
	Untreated Solvent				Treated Solvent			
	R1-03 ^{a,c} (ITAS)	R2-03 ^{a,d} (ITAS)	R2-03 ^{b,d} (Battelle)	R3-03 ^{a,e} (ITAS)	R1-04 ^a (ITAS)	R1-04 ^b (Battelle)	R1-04B dupl ^b (Battelle)	
<u>Dioxins</u>								
Total TCDD	NA ^g	798	862	229	6.8	14.1	29.1	29.8
2,3,7,8-TCDD	210	780	671	222	<0.69 ^f	<0.85 ^f	0.33	0.44
Total P ₅ CDD	NA	237	1680	25.5	4.1	8.0	54.7	53.6
Total H ₄ CDD	NA	102	508	15.0	<0.57	<0.94	3.40	3.71
<u>Furans</u>								
Total TCDF	NA	157	1203	8.6	1.9	3.4	105	97
2,3,7,8-TCDF	NA	46.2	177	12.3	0.27	0.56	0.85	0.95
Total P ₅ CDF	NA	52.6	686	3.6	<0.14	<0.29	5.73	5.66
Total H ₄ CDF	NA	8.1	36.0	<0.47 ^f	<0.27	<0.74	<0.042 ^f	<0.030 ^f

a. See Appendix R, Exhibit 1, for ITAS data sheets.

b. See Appendix T for Battelle data sheets.

c. Sample taken of scrubber solvent at end of desorption. Test Run 1.

d. Sample taken of scrubber solvent at end of desorption Test Run 2A; however, the same solvent was used from Runs 1, 2, and 2A, thus allowing buildup of dioxin/furan concentrations.

e. Sample taken of scrubber solvent at end of Run 3. Fresh solvent was used for this run.

f. Not detected. Detection limit value shown.

g. NA means not analyzed.

Sample R2-03 taken after 2A. The 2,3,7,8-TCDD concentration was shown to increase to 780 ppb, based on ITAS analysis, and 671 ppb, based on Battelle analysis. This solvent batch was then used as the feed solvent for the UV photolysis test run. Fresh solvent was used during desorption Test Run 3. The resulting 2,3,7,8-TCDD concentration in the solvent for this run was 222 ppb, based on ITAS analysis. This concentration is close to that found for Run 1 shown above. Solvent contamination levels are a function of the amount of soil treated, which varied between desorption tests, as shown in Table 3. It is interesting to observe in Table 17 the presence of other congeners in Sample R2-03 besides TCDD. The Battelle data show P₅CDD and TCDF in concentrations (1680 and 1203 ppb) greater than the TCDD (862 ppb), with the other congeners (P₅CDF, H_xDD, and H_xCDF) having significant concentrations. As previously mentioned in Section V.A.4.a, the Battelle results for feedstock in Run 1 show P₅CDD and TCDF present well above 1 ppm. The ITAS analysis for the scrubber solvent from Run 2A does show presence of these other dioxin/furan congeners; however, the concentrations are substantially less than those found by Battelle. The TCDD and 2,3,7,8-TCDD specific analytical results for the two laboratories are in fair agreement.

The analytical results for volatile organic components in the two scrubber solvent samples analyzed (R2-03, R3-03) are shown in Table 18. The following volatiles on the PPL (Appendix I) were detected with concentrations shown:

<u>Volatile Component</u>	<u>Concentration (ppm)</u>	
	<u>R2-03</u>	<u>R3-03</u>
Benzene	23.0	4.8
Ethyl benzene	6.9	2.3
Methylene chloride	4.0	4.6
Toluene	44.0	9.4

The methylene chloride was also observed in the method blank, which indicates that those results are due to contamination. The other three show a trend related to the amount of soil treated during the desorption

TABLE 18. VOLATILE ORGANIC COMPONENT CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES

Component	Concentration ^a (ppm)			
	Untreated Solvent		Treated Solvent	
	R2-03 ^b	R3-03 ^c	R1-04 ^a	R1-04A ^a
Acrolein	<1.0 ^f	<1.0 ^f	<1.0 ^f	<1.0 ^f
Acrylonitrile	<1.0	<1.0	<1.0	<1.0
Benzene	23.0	4.85	28.0	26.0
Carbon Tetrachloromethane (carbon tetrachloride)	<0.5	<0.5	<0.5	<0.5
Chlorobenzene	<0.5	<0.5	<0.5	<0.5
1,2-Dichloroethane	<0.5	<0.5	<0.5	<0.5
1,1,1-Trichloroethane	<0.5	<0.5	<0.5	<0.5
1,1-Dichloroethane	<0.5	<0.5	<0.5	<0.5
1,1,2-Trichloroethane	<0.5	<0.5	<0.5	<0.5
1,1,2,2-Tetrachloroethane	<0.5	<0.5	<0.5	<0.5
Chloroethane (ethyl chloride)	<1.0	<1.0	<1.0	<1.0
2-Chloroethyl vinyl ether	<1.0	<1.0	<1.0	<1.0
Trichloromethane (chloroform)	<0.5	<0.5	<0.5	<0.5
1,1-Dichloroethene	<0.5	<0.5	<0.5	<0.5
Trans-1,2-dichloroethene	<0.5	<0.5	<0.5	<0.5
1,2 Dichloropropane	<0.5	<0.5	<0.5	<0.5
1,3-Dichloropropane	<0.5	<0.5	<0.5	<0.5
Ethyl benzene	6.9	2.3	8.9	7.7
Dichloromethane (methylene chloride)	4.0 ^g	4.6 ^{g,h}	450 ^g	410 ^g
Chloromethane (methyl chloride)	<1.0	<1.0	<1.0	<1.0
Bromomethane (methyl bromide)	<1.0	<1.0	<1.0	<1.0
Tribromomethane (bromoform)	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	<0.5	<0.5	<0.5	<0.5
Tetrachloroethene	1.1	<0.5	<0.5	<0.5

TABLE 18. VOLATILE ORGANIC COMPONENT CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES (CONCLUDED)

Component	Concentration ^a (ppm)			
	Untreated Solvent		Treated Solvent	
	R2-03 ^b	R3-03 ^c	R1-04 ^a	R1-04A ^e
Toluene	44.0	9.4	60.0	50.0
Trichloroethene	<0.5	<0.5	<0.5	<0.5
Chloroethene (vinyl chloride)	<1.0	<1.0	<1.0	<1.0

a. See Appendix S, Exhibit 2, for ITAS data sheets.

b. Scrubber solvent batch sample from desorber Runs 1 and 2/2A; represents input solvent for UV photolysis test run; ITAS Lab No. AA0655.

c. Scrubber solvent sample from desorber Run 3; ITAS Lab No. AA0658.

d. Treated solvent sample from end of UV photolysis test run; ITAS Lab No. AA0659.

e. Treated solvent sample field duplicate from end of UV photolysis test run; ITAS Lab No. AA0660.

f. Not detected. Detection limit value shown.

g. Analyte was found in the blank as well as the sample. Indicates possible blank contamination.

h. Indicates an estimated value.

runs applicable to each scrubber solvent batch. Sample R2-03 represents buildup from Runs 1 and 2/2A. Detection limit values for the remaining PPL volatiles analyzed were 1.0 ppm or less, which meets the analytical requirement.

The analytical results for semivolatile organic components in the two scrubber solvent samples analyzed (R2-03, R3-03) are shown in

Table 19. The following semivolatiles on the PPL (Appendix I) were detected with concentrations shown:

<u>Semivolatile Component</u>	<u>Concentration (ppm)</u>	
	<u>R2-03</u>	<u>R3-03</u>
2-Chlorophenol	5.8	2.0
2,4-Dichlorophenol	200	73.3
Phenol	12.0	8.9 (estimated)

In addition, 2,4,5-trichlorophenol, which is not identified on the PPL, was shown to have concentrations of 230 and 70 ppm for Samples R2-03 and R3-03. Each of these semivolatiles is identified with HO. The DLVs for the rest of the semivolatiles on the PPL ranged from 1 to 20 ppm, with very few at 1 ppm, which was the analytical requirement.

The analytical results for organochlorine pesticides and PCBs in the two scrubber solvent samples analyzed (R2-03, R3-03) are shown in Table 20. None were detected. The DLVs ranged from 1 to 10 ppm, with the analytical requirement of 1 ppm.

The analytical results for inorganics in the two scrubber solvent samples analyzed (R2-03, R3-03) are shown in Table 21. Except for total cyanide in Sample R2-03, which was 1.3 ppm, all inorganics were either detected at less than 1 ppm or had DLVs less than 1 ppm, as required.

d. Photolyzed Solvent

Table 17 compares the PCDD and PCDF results for treated scrubber solvent (ITAS Samples R1-04, R1-04A and Battelle Sample R1-04B) with the results of the untreated solvent (ITAS and Battelle samples for R2-03) used in the UV photolysis test. These treated solvent samples represent the end of the test, which lasted 12.3 hours. Data from both laboratories indicate that substantial reduction of PCDD/PCDF occurred and

TABLE 19. SEMIVOLATILE ORGANIC COMPOUND CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES

Component ^b	Concentration ^a (ppm)			
	Untreated Solvent		Treated Solvent	
	R2-03 ^c	R3-03 ^d	R1-04 ^e	R1-04A ^f
<u>Acid Type</u>				
2,4,6-Trichlorophenol	<1.0 ^{g,h}	<1.0 ^{g,i}	<5.0 ^{g,i}	<20 ^g
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	<1.0	<1.0	<1.0	<20
2-Chlorophenol	5.8	2.0 ^k	0.25 ^k	<20
2,4-Dichlorophenol	200	73	<1.0	<20
2,4-Dimethylphenol	4.8	<1.0	<1.0	<20
2-Nitrophenol	<1.0	<1.0	<1.0	<20
4-Nitrophenol	<5.0	<5.0	<5.0	<100
2,4-Dinitrophenol	<5.0	<5.0	<5.0	<100
2-Methyl-4,6-dinitrophenol (4,6-Dinitro-o-cresol)	<50	<5.0	<1.0	<100
Pentachlorophenol	<5.0	<5.0	<5.0	<100
Phenol	12.0	8.9 ^k	37.0	78
<u>Base/Neutral Type</u>				
Acenaphthene	<10.0	<10.0	<10.0	<20
1,2,4-Trichlorobenzene	<10.0	<10.0	<10.0	<20
Hexachlorobenzene	<10.0	<10.0	<10.0	<20
Hexachloroethane	<10.0	<10.0	<10.0	<20
bis (2-Chloroethyl) ether	<10.0	<10.0	<10.0	<20
2-Chloronaphthalene	<10.0	<10.0	<10.0	<20
1,2-Dichlorobenzene				
1,3-Dichlorobenzene	<10.0	<10.0	<10.0	<20
1,4-Dichlorobenzene	<10.0	<10.0	<10.0	<20
3,3'-Dichlorobenzidine	<20.0	<20.0	<20.0	<40
2,4-Dinitrotoluene	<10.0	<10.0	<10.0	<20
2,6-Dinitrotoluene	<10.0	<10.0	<10.0	<20
Fluoranthene	<10.0	<10.0	<10.0	<20
4-Chlorophenyl phenyl ether	<10.0	<10.0	<10.0	<20
4-Bromophenyl phenyl ether	<10.0	<10.0	<10.0	<20

TABLE 19. SEMIVOLATILE ORGANIC COMPOUND CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES (CONTINUED)

Component ^b	Concentration ^a (ppm)			
	Untreated Solvent		Treated Solvent	
	R2-03 ^c	R3-03 ^d	R1-04 ^e	R1-04A ^f
bis (2-Chloroisopropyl) ether	<10.0	<10.0	<10.0	<20
bis (2-Chloroethoxy) methane	<10.0	<10.0	<10.0	<20
Hexachlorobutadiene	<10.0	<10.0	<10.0	<20
Hexachlorocyclopentadiene	<10.0	<10.0	<10.0	<20
Isophorone	<10.0	<10.0	<10.0	<20
Naphthalene	<10.0	<10.0	<10.0	<20
Nitrobenzene	<10.0	<10.0	<10.0	<20
Diphenyl nitrosamine (N-nitrosodiphenylamine)	<10.0	<10.0	<10.0	<20
Di-n-propyl nitrosamine (N-Nitrosodi-n-propylamine)	<10.0	<10.0	<10.0	<20
bis (2-Ethylhexyl) phthalate	<10.0	<10.0	<10.0	<20
Benzyl butyl phthalate	<10.0	<10.0	<10.0	<20
Di-n-butyl phthalate	<10.0	<10.0	<10.0	2.8
Di-n-octyl phthalate	<10.0	<10.0	9.1 ^k	16.0 ^k
Diethylphthalate	<10.0	<10.0	<10.0	<20
Dimethyl phthalate	<10.0	<10.0	<10.0	<20
Benzo(a)anthracene	<10.0	<10.0	<10.0	<20
Benzo(a)pyrene	<10.0	<10.0	<10.0	<20
Benzo(b)fluoranthene	<10.0	<10.0	<10.0	<20
Benzo(k)fluoranthene	<10.0	<10.0	<10.0	<20
Chrysene	<10.0	<10.0	<10.0	<20
Acenaphthylene	<10.0	<10.0	<10.0	<20
Anthracene	<10.0	<10.0	<10.0	<20
Benzo(g,h,i)perylene	<10.0	<10.0	<10.0	<20
Fluorene	<10.0	<10.0	<10.0	<20

TABLE 19. SEMIVOLATILE ORGANIC COMPOUND CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES (CONCLUDED)

Component ^b	Concentration ^a (ppm)			
	Untreated Solvent		Treated Solvent	
	R2-03 ^c	R3-03 ^d	R1-04 ^e	R1-04A ^f
Phenanthrene	<10.0	<10.0	<10.0	<20
Dibenzo(a,h)anthracene	<10.0	<10.0	<10.0	<20
Indeno(1,2,3-c,d)pyrene	<10.0	<10.0	<10.0	<20
Pyrene	<10.0	<10.0	<10.0	<20

a. See Appendix S, Exhibit 2 for ITAS data sheets.

b. Analysis not made for benzidine dimethyl nitrosamine (N-nitrosodimethylamine) as listed in the modified PPL (see Appendix I).

c. Scrubber solvent batch sample from desorber Runs 1 and 2/2A; represents input solvent for UV photolysis test run; ITAS Lab No. AA0655.

d. Scrubber solvent sample from desorber Run 3; ITAS Lab No. AA0658.

e. Treated solvent sample from end of UV photolysis test run; ITAS Lab No. AA0659.

f. Treated solvent sample field duplicate from end of UV photolysis test run; ITAS Lab No. AA0660.

g. Not detected. Detection limit value shown.

h. Although not on PPL, 2,4,5-trichlorophenol concentration was 230 ppm.

i. 2,4,5-trichlorophenol concentration was 70 ppm.

j. 2,4,5-trichlorophenol was not detected. DLV was 5.0 ppm.

k. Indicates an estimated value.

TABLE 20. ORGANOCHLORINE PESTICIDE AND PCB CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES

Components	Concentration ^a (ppm)			
	Untreated Solvent		Treated Solvent	
	R2-03 ^b	R3-03 ^c	R1-04 ^d	R1-04A ^e
Aldrin	<1.0 ^f	<1.0 ^f	<1.0 ^f	<1.0 ^f
Alpha-BHC	<1.0	<1.0	<1.0	<1.0
Beta-BHC	<2.0	<1.0	<1.0	<1.0
Gamma-BHC (Lindane)	<1.0	<1.0	<1.0	<1.0
Delta-BHC	<2.0	<1.0	<1.0	<1.0
Chlordane	<1.0	<1.0	<1.0	<1.0
4,4'-DDD	<1.0	<1.0	<1.0	<1.0
4,4'-DDE	<1.0	<1.0	<1.0	<1.0
4,4'-DDT	<1.0	<1.0	<1.0	<1.0
Dieldrin	<1.0	<1.0	<1.0	<1.0
Endosulfan I	<1.0	<1.0	<1.0	<1.0
Endosulfan II	<1.0	<1.0	<1.0	<1.0
Endosulfan sulfate	<1.0	<1.0	<1.0	<1.0
Endrin	<1.0	<1.0	<1.0	<1.0
Endrin aldehyde	<1.0	<1.0	<1.0	<1.0
Heptachlor epoxide	<1.0	<1.0	<1.0	<1.0
Toxaphene	<5.0	<5.0	<5.0	<5.0
PCB-1016	<5.0	<5.0	<5.0	<5.0
PCB-1221	<5.0	<10.0	<5.0	<5.0
PCB-1232	<5.0	<9.0	<5.0	<5.0
PCB-1242	<5.0	<5.0	<5.0	<5.0
PCB-1248	<5.0	<6.0	<5.0	<5.0
PCB-1254	<5.0	<5.0	<5.0	<5.0
PCB-1260	<5.0	<5.0	<5.0	<5.0

a. See Appendix S, Exhibit 2, for ITAS data sheets.

b. Scrubber solvent batch sample from desorber Runs 1 and 2/2A; represents input solvent for UV photolysis test run; ITAS Lab No. AA0655.

c. Scrubber solvent sample from desorber Run 3; ITAS Lab No. AA0658.

d. Treated solvent sample from end of UV photolysis test run; ITAS Lab No. AA0659.

e. Treated solvent sample field duplicate from end of UV photolysis test run; ITAS Lab No. AA0660.

f. Not detected. Detection limit value shown.

TABLE 21. INORGANIC CONCENTRATIONS IN UNTREATED AND TREATED SCRUBBER SOLVENT SAMPLES

Element	Concentration ^a (ppm)		
	Untreated Solvent		Treated Solvent
	R2-03 ^b	R3-03 ^c	R1-04 ^d
Antimony	<0.2 ^e	<0.3 ^e	<0.3 ^e
Arsenic	<0.03	<0.03	<0.03
Barium ^f	<0.01	<0.01	<0.01
Beryllium	0.02	0.02	0.02
Cadmium	0.02	<0.02	<0.01
Chromium	0.32	0.11 ^g	0.11 ^g
Copper	0.11	0.05	0.05
Lead	0.03 ^h	0.05 ^h	0.05 ^h
Mercury	0.002 ^g	<0.002 ^g	<0.002 ^g
Nickel	0.15 ^g	<0.1 ^g	<0.1 ^g
Selenium	<0.01	<0.01	<0.01
Silver	<0.09	<0.005	<0.005
Thallium	<0.01	<0.01	<0.01
Zinc	<0.28 ^{g,i}	0.04 ^{g,i}	0.04 ^{g,i}
Total cyanide	1.3	0.65	0.65

a. See Appendix S, Exhibit 4, for ITAS data sheets.

b. Scrubber solvent batch sample from desorber Runs 1 and 2/2A; represents input solvent for UV photolysis test run; ITAS Lab No. AA0655.

c. Scrubber solvent sample from desorber Run 3; ITAS Lab No. AA0658.

d. Treated solvent sample from end of UV photolysis test run; ITAS Lab No. AA0659.

e. Not detected. Detection limit value shown.

f. Barium is not on the PPL (Appendix I), but is an element listed in the EP Toxicity test per 40 CFR 261.24.

g. Duplicate analysis was not within control limits.

h. Value was determined by method of standard addition.

i. Spike sample recovery was not within control units.

the 2,3,7,8-TCDD specific results were less than 1 ppb. However, PCDD/PCDF congener data showed results well above 1 ppb. For example, the Battelle data (R1-04B) showed TCDF, P₅CDD, and TCDD at 105, 55, and 29 ppb, respectively. The ITAS samples were considerably lower in magnitude for TCDF and P₅CDD, which is consistent with the bias mentioned earlier. During the UV photolysis test, samples were taken at intervals and analyzed by ITAS to determine the concentration of 2,3,7,8-TCDD and 2,3,7,8-TCDF as a function of operating time. The results are tabulated below.

TABLE 22. 2,3,7,8-TCDD AND 2,3,7,8-TCDF CONCENTRATIONS IN TREATED SOLVENT WITH UV PHOTOLYSIS TEST

Total Operating Time (hours)	Sample	Concentration ^a (ppb)	
		2,3,7,8-TCDD	2,3,7,8-TCDF
0	R2-03 ^b	780	46.2
3.2	R1-03A	159	NA ^c
4.7	R1-03B	79.3	9.1
10.3	R1-03C	0.91	NA ^c
12.3	R1-04, R1-04A	<0.69, <0.85	0.27, 0.56

a. See Appendix R, Exhibit 1, for ITAS data sheets

b. Represents untreated solvent from Runs 1 and 2/2A.

c. NA means "not analyzed".

Both sets of kinetic data are plotted in Figure 39; test conditions were a flow rate of 0.20 gpm, a temperature of 90 °F, and a 1200-watt UV lamp.

Table 18 shows the volatile organic analytical results for the treated solvent samples (R1-04 and R1-04A) for comparison with the untreated scrubber solvent sample (R2-03). As listed below, the detected components in the untreated solvent remain in the treated solvent, with the concentration of methylene chloride increased by two orders of magnitude.

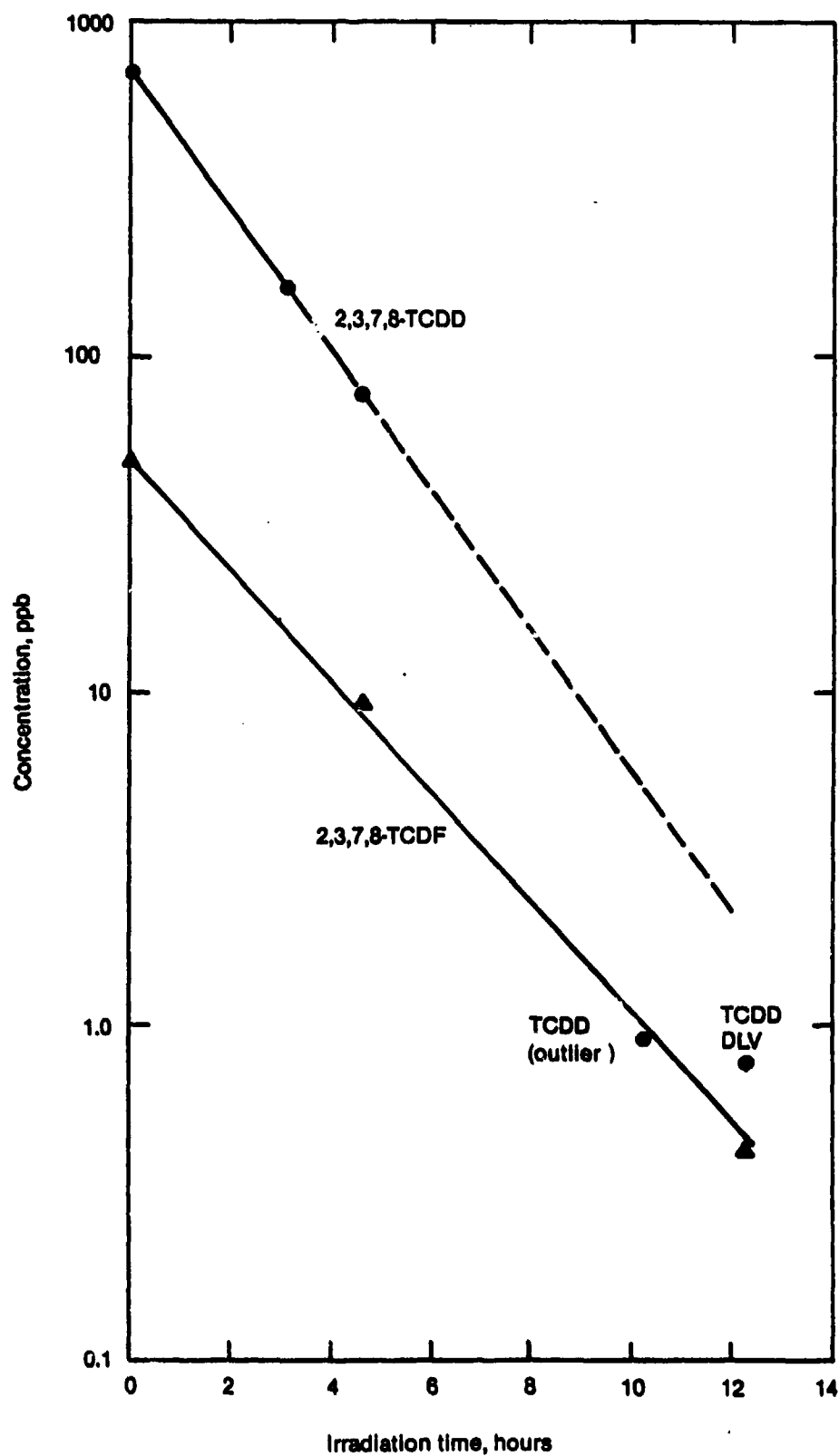


Figure 39. 2,3,7,8-TCDD and 2,3,7,8-TCDF Concentrations as a Function of Irradiation Time During JI UV Photolysis Test of Scrubber Solvent.

<u>Volatile Component</u>	<u>Concentration (ppm)</u>	
	<u>R1-04</u>	<u>R1-04A</u>
Benzene	28.0	26.0
Ethyl benzene	8.9	7.7
Methylene chloride	450	410
Toluene	60	50

The ITAS data sheets show that the method blank indicated presence of methylene chloride, but the above concentrations were quite high to represent the possibility of contamination. Detection limit values for the remaining PPL volatiles analyzed were 1.0 ppm or less, as required.

Table 19 shows the semivolatile organic analytical results for the treated solvent samples (R1-04 and R1-04A) for comparison with the untreated scrubber solvent sample (R2-03). The data for Sample R1-04 showed detectable concentrations of phenol (37 ppm) and di-n-octyl phthalate (9.1 ppm). The phenol was previously observed in the untreated solvent sample. Di-n-octyl phthalate was not observed in the untreated solvent because of a high DLV (10 ppm). This component was observed in the treated solvent field duplicate sample at 16 ppm as was phenol at 78 ppm. For Sample R1-04, the DLV ranges were 1 to 20 ppm like the untreated samples. The DLVs for the duplicate sample were extremely high, ranging from 20 to 100 ppm.

The organochlorine pesticide and PCB analytical results for Samples R1-04 and R1-04A are shown in Table 20. As with the untreated solvent, none of the PPL components was detected, with DLVs ranging between 1 and 5 ppm.

The inorganic analytical results for the treated solvent samples (R1-04 and R1-04A) are shown in Table 20. The concentrations of detected elements and the DLVs of the rest are below 1 ppm and are consistent with the results shown for the untreated solvent sample (R2-03).

e. Filter Solids (Composite)

The single composite sample of solids from the solvent filter media representing all desorption tests (Sample R1-3-06) was analyzed for isomer-specific 2,3,7,8-TCDD. The concentration of 2,3,7,8-TCDD was found to be 232 ppb (Appendix R, Exhibit 1, for data sheet), which is consistent with the untreated solvent results shown in Table 17. The sample consisted of 62 percent solids and 38 percent scrubber solvent (Appendix S, Exhibit 5).

f. Aqueous Condensate

Approximately 80 pounds of aqueous phase were separated from the scrubber following desorber Runs 1 and 2/2A. Analyses were performed on a sample (R1-2-05) of this condensate after filtration (0.45 micron retention). The analytical parameters were selected to determine the treatment characteristics of this process wastewater and to provide a basis for projecting equipment and operating requirements for a full-scale wastewater treatment system. Results for the selected parameters are shown in Table 23. The isomer-specific concentration of 2,3,7,8-TCDD was found to be 221 ppb, which is consistent in magnitude with the untreated solvent (Table 17) and the composite solids, which were discussed in the previous paragraph. Two of the acid extractable organics on the PPL (Appendix I) were detected in significant concentration: 2,4-dichlorophenol at 91 ppm and phenol at 57 ppm. Although not on the PPL, 2,4,5-trichlorophenol was detected at a concentration of 180 ppm. All three organic components are related to HO. Other organic priority pollutants (e.g., volatiles, base/neutral extractable, organochlorine pesticides, and PCBs) were not determined.

Phenolics corresponding to those found in the scrubber solvent total 335 ppm; other quantified organics total 127 ppm. A comparison of these values with the total organic carbon (TOC) value of 1,970 ppm (Table 22) indicates that a considerable portion of the organic content is unaccounted for. Based on the identification of a variety of

TABLE 23. ANALYTICAL RESULTS FOR AQUEOUS CONDENSATE COLLECTED FROM
DESORPTION RUNS 1 and 2/2A

Parameter	Concentration ^a (ppm unless otherwise stated)
pH	8.26
Chloride	29
Total organic carbon (TOC)	1,970
2,3,7,8-TCDD	221 ppb ^b
Acid extractable priority pollutants ^c	
2,4,6-Trichlorophenol	<2.0 ^{d,e}
4-Chloro-3-methylphenol	<2.0
2-Chlorophenol	4.6
2,4-Dichlorophenol	91.0
2,4-Dimethylphenol	1.8
2-Nitrophenol	<2.0
4-Nitrophenol	<2.0
2,4-Dinitrophenol	<10.0
2-Methyl-4,6-dinitrophenol	<10.0
Pentachlorophenol	<2.0
Phenol	57.0

a. Sample ID: R1-2-05; ITAS Lab No. 3533, water. Unless otherwise stated, see Appendix S, Exhibit 5, for ITAS data sheets.

b. Isomer-specific analysis. See Appendix R, Exhibit 1, for ITAS data sheet.

c. See Appendix I for PPL.

d. Not detected. Detection limit value shown.

e. Although not on the PPL, the concentration for 2,4,5-trichlorophenol was analyzed and found to be 180 ppm.

oxygenated organics, such as alcohols and carboxylic acids, in the scrubber solvent (Appendix S, Exhibit 2), it is likely that these same compounds, which have significant solubility in water, make up the major portion of TOC.

g. Vent Activated Carbon

The PCDD and PCDF results for the primary activated carbon filter samples (R2-09, R3-09) and the secondary guard absorber carbon

composite sample (R1-3-10) are shown in Table 24. No PCDD/PCDF congeners were detected; however, the DLVs ranged from 0.029 to 1.0 ppb.

The analytical results for PPL volatile organic components in the primary and secondary vent filter samples (R3-09, R1-3-10) of spent carbon are shown in Table 25. Methylene chloride in concentrations ranging from 720 to 770 ppm was found in the three analyses, which included the laboratory duplicate of R3-09. Other PPL volatiles were extremely low in concentration or not detectable, with DLVs well below 1 ppm. The ITAS data sheet indicates that methylene chloride was also found in the blank, suggesting possible contamination. Virgin carbon shipped to JI to load these filters but not used was also analyzed (sample identified as JI-IT-02; AA0619). As shown on the ITAS data sheet (Appendix S, Exhibit 2), a methylene chloride concentration of 2500 ppm was determined, with the same blank contamination footnote included. These results indicate the source was not process-related. Additional non-PPL analysis shows the presence of 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) in the spent and virgin carbon samples as listed below.

<u>Sample</u>	<u>Concentration (ppm)</u>
R3-09	27,000
R3-09D	840
R1-3-10	29,000
IT-02 (virgin)	33,000

In reviewing the problem, ITC suggests that the contamination may have been caused by leakage of these two highly volatile materials from standard containers (as received from suppliers) at JI. Both of these materials, which were to be used for equipment decontamination, were packaged by ITC and later crated by Holmes and Narver with the lined fiber drum of virgin granular carbon, which offered an opportunity for escaped vapors to transfer and be adsorbed.

TABLE 24. POLYCHLORODIBENZO-P-DIOXIN AND POLYCHLORODIBENZOFURAN
CONCENTRATIONS IN DESORPTION TEST OFF-GAS ACTIVATED
CHARCOAL FILTER SAMPLES

<u>PCDD/PCDF</u>	Concentration ^a (ppm)		
	<u>Primary Filter</u>		<u>Secondary Filter</u>
	<u>R2-03^b</u>	<u>R3-03^c</u>	<u>R1-3-10^d</u>
<u>Dioxins</u>			
Total TCDD	NA ^e	<0.033 ^f	<0.19 ^f
2,3,7,8-TCDD	<0.36 ^f	<0.16 ^g	<0.22
Total P ₅ CDD	NA	<0.47	<0.22
Total H _x CDD	NA	<1.0	<0.20
<u>Furans</u>			
Total TCDF	NA	<0.032	<0.030
2,3,7,8-TCDF	NA	<0.086 ^g	<0.14
Total P ₅ CDF	NA	<0.029	<0.043
Total H _x CDF	NA	<0.16	<0.20

a. See Appendix R, Exhibit 1, for ITAS data sheets.

b. Represents primary filter activated carbon material for desorber Run 2/2A; ITAS Lab No. J3511.

c. Represents primary filter activated carbon material for desorber Run 3; ITAS Lab No. J3524.

d. Represents secondary adsorber activated carbon material composite sample for all desorber runs; ITAS Lab No. J3531.

e. NA means not analyzed.

f. Not detected. Detection limit value shown.

g. A lab duplicate, R3-09D, showed DLVs of 0.49 ppb for 2,3,7,8-TCDD and 0.22 for 2,3,7,8-TCDF.

TABLE 25. VOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST
OFF-GAS ACTIVATED CHARCOAL FILTER SAMPLES

Component	Concentration ^a (ppm)		
	Primary Filter		Secondary Filter
	R3-09 ^b	R3-09D ^c	R1-3-10 ^d
Acrolein	NA ^e	NA ^e	NA ^e
Acrylonitrile	NA	NA	NA
Benzene	0.080	1.10	<0.005
Carbon Tetrachloromethane (carbon tetrachloride)	<0.025 ^f	<0.009 ^f	<0.005
Chlorobenzene	<0.025	<0.009	<0.005
1,2-Dichloroethane	<0.025	<0.009	<0.005
1,1,1-Trichloroethane	<0.025	0.91	0.60
1,1-Dichloroethane	<0.025	<0.009	<0.005
1,1,2-Trichloroethane	<0.025	<0.009	<0.005
1,1,2,2-Tetrachloroethane	<0.025	<0.009	<0.005
Chloroethane (ethylchloride)	0.24	0.065	0.014
2-Chloroethyl vinyl ether	<0.025	<0.018	<0.010
Trichloromethane (chloroform)	<0.025	<0.009	<0.005
1,1-Dichloroethene	<0.025	<0.009	<0.005
Trans-1,2-dichloroethene	<0.025	<0.009	<0.005
1,2 Dichloropropane	<0.025	<0.009	<0.005
1,3-Dichloropropane	<0.025	<0.009	<0.005
Ethyl benzene	<0.025	<0.009	<0.005
Dichloromethane (methylene chloride)	720 ^g	770 ^g	720 ^g
Chloromethane (methyl chloride)	2.5	0.28	0.20
Bromomethane (methyl bromide)	<0.050	0.011	0.0058 ^h
Tribromomethane (bromoform)	<0.025	<0.009	<0.005
Bromodichloromethane	<0.025	<0.009	<0.005
Dibromochloromethane	<0.025	<0.009	<0.005
Tetrachloroethene	<0.025	<0.009	<0.005

TABLE 25. VOLATILE ORGANIC COMPONENT CONCENTRATIONS IN DESORPTION TEST
OFF-GAS ACTIVATED CHARCOAL FILTER SAMPLES (CONCLUDED)

Component	Concentration ^a (ppm)		
	Primary Filter		Secondary Filter
	R3-09 ^b	R3-09D ^c	R1-3-10 ^d
Toluene	0.049	<0.009	<0.005
Trichloroethene	<0.025	<0.009	<0.005
Chloroethene (vinyl chloride)	<0.050	<0.018	<0.010

a. See Appendix S, Exhibit 2, for ITAS data sheets.

b. Represents primary filter activated carbon material for desorber Run 3; ITAS Lab No. AA0651.

c. Represents lab duplicate of primary filter activated carbon material for desorber Run 3; ITAS Lab No. AA0652.

d. Represents secondary adsorber activated carbon material composite sample for all desorber runs; ITAS Lab No. AA0653.

e. NA indicates not analyzed.

f. Not detected. Detection limit value shown.

g. Analyte was found in the blank as well as the sample. Indicates possible blank contamination.

h. Indicates an estimated value.

During unpacking, it was discovered that one 60-pound factory-sealed Freon[®] cylinder had leaked. No obvious loss of methylene chloride was established, although minor leakage from all or most of the eight cans could contribute sufficient quantity to correspond to the levels found in the carbon. Analysis of the virgin carbon showed approximate carbon loadings of 0.0025 g/g and 0.03 g/g for methylene chloride and Freon 113, respectively. Assuming the entire contents of the carbon fiber

drum was at that concentration, the total quantity of these compounds adsorbed was approximately 45 and 540 grams, respectively.

For each of the three desorption tests at JI, approximately 3,000 grams of virgin carbon were placed into the primary vent adsorber; a single 3,000-gram charge was used in the secondary adsorber for all tests. Each charge contained an estimated 7.5 grams of methylene chloride and 90 grams of Freon 113. Measurement of these compounds in the spent carbon from the primary and secondary adsorbers and comparison with the virgin carbon indicate that some loss or desorption occurred, although the concentrations were at the upper limit of the analytical method and a quantitative loss cannot be determined by difference. A 1 percent desorption loss would represent 75 mg of methylene chloride and 900 mg of Freon 113 that would be contained in the process vent sampled downstream.

The analytical results for the PPL semivolatile organic components in the primary and secondary vent filter samples (R3-09, R1-3-10) of spent carbon are shown in Table 26. In primary filter Sample R3-09, only phenol at 1.4 ppm and 2,4-dichlorophenol at 1.3 ppm were detected above 1 ppm. In the laboratory duplicate, the phenol was 3.2 ppm and the 2,4-dichlorophenol was not detected at a DLV of 0.33 ppm. Semivolatiles on the PPL were not detected above 1 ppm in the secondary adsorber composite sample. DLVs for all three sample analyses ranged from 0.33 to 1.60 ppm.

As indicated by review of the data sheets in Appendix S, Exhibit 2, for the vent carbon samples, no organochlorine pesticides or PCBs were detected above 1 ppm. However, a 0.56 ppm concentration of Aroclor-254 was observed in primary filter sample R3-09. The laboratory duplicate sample showed a DLV of 0.18 for this component. All other DLVs ranged from 0.008 to 0.16 ppm.

The analytical results for PPL inorganics in the primary and secondary vent filter samples (R3-09, R1-3-10) of spent carbon are shown in Table 27. Zinc was most significant at concentrations of 73 and 326 ppm in the R3-09 and R1-3-10 samples, respectively. Sample R3-09 also showed

TABLE 26. SEMIVOLATILE ORGANIC COMPOUND CONCENTRATIONS IN DESORPTION TEST
OFF-GAS ACTIVATED CHARCOAL FILTER SAMPLES

Component ^b	Concentration ^a (ppm)		
	Primary Filter		Secondary Filter
	R3-09 ^c	R3-09D ^d	R1-3-10 ^e
<u>Acid Type</u>			
2,4,6-Trichlorophenol	<0.33 ^f	<0.33 ^f	<0.33 ^f
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	<0.33	<0.33	<0.33
2-Chlorophenol	<0.33	<0.33	<0.33
2,4-Dichlorophenol	1.30	<0.33	<0.33
2,4-Dimethylphenol	<0.33	<0.33	<0.33
2-Nitrophenol	<0.33	<0.33	<0.33
4-Nitrophenol	<1.60	<1.60	<1.60
2,4-Dinitrophenol	<1.60	<1.60	<1.60
2-Methyl-4,6-dinitrophenol (4,6-Dinitro-o-cresol)	<1.60	<1.60	<1.60
Pentachlorophenol	<1.60	<1.60	<1.60
Phenol	1.4	3.2	<0.33
<u>Base/Neutral Type</u>			
Acenaphthene	<0.33	<0.33	<0.33
1,2,4-Trichlorobenzene	<0.33	<0.33	<0.33
Hexachlorobenzene	<0.33	<0.33	<0.33
Hexachloroethane	<0.33	<0.33	<0.33
bis (2-Chloroethyl) ether	<0.33	<0.33	<0.33
2-Chloronaphthalene	<0.33	<0.33	<0.33
1,2-Dichlorobenzene	<0.33	<0.33	<0.33
1,3-Dichlorobenzene	<0.33	<0.33	<0.33
1,4-Dichlorobenzene	<0.33	<0.33	<0.33
3,3'-Dichlorobenzidine	<0.66	<0.66	<0.66
2,4-Dinitrotoluene	<0.33	<0.33	<0.33
2,6-Dinitrotoluene	<0.33	<0.33	<0.33
Fluoranthene	<0.33	<0.33	<0.33
4-Chlorophenyl phenyl ether	<0.33	<0.33	<0.33
4-Bromophenyl phenyl ether	<0.33	<0.33	<0.33

TABLE 26. SEMIVOLATILE ORGANIC COMPOUND CONCENTRATIONS IN DESORPTION TEST
OFF-GAS ACTIVATED CHARCOAL FILTER SAMPLES (CONTINUED)

Component ^b	Concentration ^a (ppm)		
	Primary Filter		Secondary Filter
	R3-09 ^c	R3-09D ^d	R1-3-10 ^e
bis (2-Chloroisopropyl) ether	<0.33	<0.33	<0.33
bis (2-Chloroethoxy) methane	<0.33	<0.33	<0.33
Hexachlorobutadiene	<0.33	<0.33	<0.33
Hexachlorocyclopentadiene	<0.33	<0.33	<0.33
Isophorone	<0.33	<0.33	<0.33
Naphthalene	<0.33	<0.33	<0.33
Nitrobenzene	<0.33	<0.33	<0.33
Diphenyl nitrosamine (N-nitrosodiphenylamine)	<0.33	<0.33	0.25 ^g
Di-n-propyl nitrosamine (N-Nitrosodi-n-propylamine)	<0.33	<0.33	<0.33
bis (2-Ethylhexyl) phthalate	0.55	0.91	0.58
Benzyl butyl phthalate	<0.33	<0.33	<0.33
Di-n-butyl phthalate	<0.33	<0.33	0.095 ^g
Di-n-octyl phthalate	<0.33	<0.33	<0.33
Diethyl phthalate	<0.33	<0.33	<0.33
Dimethyl phthalate	<0.33	<0.33	<0.33
Benzo(a)anthracene	<0.33	<0.33	<0.33
Benzo(a)pyrene	<0.33	<0.33	<0.33
Benzo(b)fluoranthene	<0.33	<0.33	<0.33
Benzo(k)fluoranthene	<0.33	<0.33	<0.33
Chrysene	<0.33	<0.33	<0.33
Acenaphthylene	<0.33	<0.33	<0.33
Anthracene	<0.33	<0.33	<0.33
Benzo(g,h,i)perylene	<0.33	<0.33	<0.33
Fluorene	<0.33	<0.33	<0.33

**TABLE 26. SEMIVOLATILE ORGANIC COMPOUND CONCENTRATIONS IN DESORPTION TEST
OFF-GAS ACTIVATED CHARCOAL FILTER SAMPLES (CONCLUDED)**

Component ^b	Concentration ^a (ppm)		
	Primary Filter		Secondary Filter
	R3-09 ^c	R3-09D ^d	R1-3-10 ^e
Phenanthrene	<0.33	<0.33	<0.33
Dibenzo(a,h)anthracene	<0.33	<0.33	<0.33
Indenol(1,2,3-c,d)pyrene	<0.33	<0.33	<0.33
Pyrene	<0.33	<0.33	<0.33

a. See Appendix S, Exhibit 2 for ITAS data sheets.

b. Analysis not made for benzidine dimethyl nitrosamine (N-nitrosodimethylamine) as listed in the modified PPL (see Appendix I).

c. Represents primary filter activated carbon material for desorber Run 3; ITAS Lab No. AA0651.

d. Represents lab duplicate of primary filter activated carbon material for desorber Run 3; ITAS Lab No. AA0652.

e. Represents secondary adsorber activated carbon material composite sample for all desorber runs; ITAS Lab No. AA0653.

f. Not detected. Detection limit value shown.

g. Indicates an estimated value.

total cyanide at 32 ppm; whereas the secondary filter material showed a DLV of 0.5 ppm. Otherwise, the results were similar between the two samples. The non-PPL element, barium, was found in substantial concentrations of 212 and 164 ppm for the primary and secondary filter samples, respectively.

As indicated by review of the data sheets in Appendix S, Exhibit 2, for Samples R3-09, R3-09D, and R1-3-10, HO constituents 2,4-D and 2,4,5-T were not detected in these samples. The DLVs were 0.010 ppm.

TABLE 27. INORGANIC CONCENTRATIONS IN DESORPTION OFF-GAS ACTIVATED CHARCOAL FILTER SAMPLES

Element	Concentration ^a (ppm)	
	Primary Filter R3-09 ^b	Secondary Filter R1-3-10 ^c
Antimony	<0.4 ^d	<0.4 ^d
Arsenic	<4	<2
Barium ^e	212	164
Beryllium	0.59	0.50
Cadmium	<0.2	<0.2
Chromium	9.5 ^f	5.8 ^f
Copper	4.5	3.5
Lead	8.6	7.7
Mercury	0.17	0.04
Nickel	5.5 ^f	3.5 ^f
Selenium	<4	<1
Silver	0.05 ^g	<0.04
Thallium	0.30	0.32
Zinc	73 ^{f,h}	326 ^{f,h}
Total cyanide	32	<0.5

a. See Appendix S, Exhibit 4, for ITAS data sheets.

b. Represents primary filter activated-carbon material for desorber Run 3; ITAS Lab No. AA0651.

c. Represents secondary adsorber activated carbon material composite sample for all desorber runs; ITAS Lab No. AA0653.

d. Not detected. Detection limit value shown.

e. Barium is not on the PPL (Appendix I), but is an element listed in the EP Toxicity test per 40 CFR 261.24.

f. Duplicate analysis was not within control limits.

g. Value was determined by method of standard addition.

h. Spike sample recovery was not within control units.

h. Vent Gas

Components of the two process vent gas samples taken by E&E for desorber Runs 2 and 3 were analyzed as follows:

- o The particulate filter placed in the process vent to sample the entire gas flow was weighed and solvent-extracted, with analysis of the extract for PCDD/PCDF, acid-extractable priority pollutant organics, and HO constituents 2,4-D and 2,4,5-T.
- o The XAD-2 resin trap at the front of the MM5 sampling train was solvent-extracted and the extract was combined with the extract from the caustic scrubber/impinger solution for analysis.
- o Caustic scrubber/impinger solutions plus water rinses from the MM5 train were combined and an aliquot was taken for HCl analysis. The remaining solution was solvent-extracted after pH adjustment and the extract was combined with the XAD-2 trap solvent extract for analysis of PCDD/PCDF and acid extractable priority pollutant organics by GC/MS.
- o VOST samples, consisting of one Tenax[®] tube and one Tenax[®]/charcoal tube, were analyzed (by desorbing each pair) for volatile organic priority pollutants and other volatile organic analysts (VOAs) detected using GC/MS. Six total pairs of tubes were taken consecutively during each sampling period, with each pair corresponding to 20 liters of total gas flow through the tubes and 20 minutes of desorber operating time. Five of six pairs were analyzed; separate analysis of each individual tube was done for one pair; for the remainder, the two tubes of each pair were analyzed as a combined unit.

In addition to these samples, a set of field blanks was taken for each sampling period and a trip blank was taken; analysis was performed for volatile organics only. The trip blank VOST sample result was comparable to the process sample VOST results, indicating possible mislabeling. Analysis was, therefore, done for additional VOST samples until a sample corresponding to a trip blank was found. The two samples that were apparently switched were R2-11-10 and R3-11-18; the results presented account for this apparent mislabeling.

Chemical analysis of these samples was performed by ITAS, and data sheets may be found in Appendix R, Exhibit 1, for PCDD/PCDF results and Appendix S, Exhibits 5 and 6, for organic and miscellaneous results. Conversion of this raw data into final form presented herein was performed by E&E, who also took the samples. The report of its work is included as Appendix P. Significant results are discussed in the following paragraphs.

Gas flow measurements from the unit were obtained with an in-line dry gas meter installed just upstream of the vent exhaust (Figure 14). Total flow through the in-line particulate filter was calculated by adding the flow through the in-line dry gas meter to the sample volumes drawn by the MM5 train and VOST. All sample volumes were corrected to standard conditions. Resulting flow characteristics are shown in Table 28.

No PCDD/PCDF were detected in the particulate or XAD-2 samples. As shown in Table 29, the DLVs for the first three congeners of dioxin and furans ranged from 23 to 820 $\mu\text{g}/\text{m}^3$.

Two composite samples, one for each test run, were formed as follows for acid-extractable organic priority pollutant analysis: J3536 from R2-11-02, R2-11-03, R2-11-04; and J3540 from R3-11-02, R3-11-03, and R3-11-04A-C. None of the 11 semivolatiles on the PPL was detected, with the DLVs being 10 ppm (see Appendix S, Exhibit 5, for ITAS data sheets).

TABLE 28. VENT GAS SAMPLING FLOW CHARACTERISTICS

Parameter	Test ^a	
	R2	R3
Average temperature	23.5°C(74°F)	25°C(77°F)
Average O ₂ content	1.4%	1.9%
Average CO ₂ content	11.6%	3.4%
Moisture content	3.8%	5%

a. Data from Appendix P.

The volatile organic component analytical results for the VOST samples for Test Runs 2 and 3 are shown in Table 30. Average concentrations are shown for each of the priority pollutants listed in Appendix I that were detected. Other classes of volatile organics (e.g., chloroparaffins, isoparaffins) also were observed. Results for the VOST analyses are complicated by the presence of methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane above the quantitation limit for the analytical protocol. In addition, the quantitation mass was saturated for chloromethane for all VOST samples. Volatile organics other than priority pollutants that were tentatively identified and quantitated included chlorofluoroparaffins originating from the contaminated vent carbon and a variety of hydrocarbons originating from the scrubber solvent. Unidentified volatile organics, which represented a significant portion of the total VOST loadings, were classified as hydrocarbons; a review of the mass spectra indicated no halogens were present.

In general, the results of individual VOST analyses for each of the two desorption tests (R2 and R3) are relatively consistent; in fact, the results of the two tests are comparable for compounds that did not saturate the mass quantitation limits. The chloroparaffins and

TABLE 29. POLYCHLORODIBENZO-P-DIOXIN AND POLYCHLORODIBENZOFURAN CONCENTRATIONS IN DESORPTION TEST PARTICULATE AND XAD-2 SAMPLES FOR RUNS 2 AND 3

<u>PCDD/PCDF</u>	Concentration ^a (10 ⁻² mg/m ³)			
	<u>Particulate Matrix</u>		<u>Gaseous Matrix</u>	
	<u>R2</u>	<u>R3</u>	<u>R2</u>	<u>R3</u>
<u>Dioxins</u>				
Total TCDD	<8.5 ^b	<13 ^b	<23 ^b	<15 ^b
2,3,7,8-TCDD	<7.5	<8.1	<20	<27
Total P ₅ CDD	<3.1	<19	<10	<5.4
Total H _x CDD	<19	<38	<79	<82
<u>Furans</u>				
Total TCDF	<12	<1.9	<4.4	<3.4
2,3,7,8-TCDF	<2.3	<4.5	<6.3	<13
Total P ₅ CDF	<6.4	<33	<15	<52
Total H _x CDF	<13	<28	<60	<19

a. For raw data, see ITAS data sheets in Appendix R, Exhibit 1, for calculated results including mass collected and volumes that apply, see E&E report in Appendix P.

b. Not detected. Detection limit value shown.

isoparaffins identified were also identified in the vent carbon from the NCBC tests (Reference 1), indicating a similar gas composition.

In interpreting these results, two questions are posed by the high levels of organics collected on the VOST resin and resin/charcoal. For chloromethane, a compound also found to be the most

TABLE 30. VOLATILE ORGANIC CONCENTRATIONS IN DESORPTION TEST VOST SAMPLES FOR RUNS 2 AND 3

Component	Concentration ^a	
	(ppm)	
	Run 2 ^b	Run 3 ^b
<u>Volatiles on PPL^c</u>		
Benzene	0.3 ^d	0.92 ^d
1,1,1-Trichloroethane	33.5	10.1
Chloroethane	185	68.1
1,1-Dichloroethane	1.4	2.5
Chloromethane (methyl chloride)	>696 ^e	>2,574 ^e
Methylene chloride	>1,838 ^e	>3,282 ^e
Bromoethane (methyl bromide)	7.65	1.3
Tetrachloroethene	1.7	2.8
Toluene	0.4 ^d	0.62 ^d
Chloroethene (vinyl chloride)	33.6	17.1
<u>Other Volatiles</u>		
1,1,2-Trichlo-1,2,2-Trifluoroethane	>1,335 ^f	>588 ^f
Trichlorofluoromethane	226 ^f	257 ^f
Other chlorofluoroparaffins	179 ^f	--
Identified isoparaffins	357 ^f	498 ^f
Acetone ^g	190	830
Unknowns	3,360 ^h	739 ^h

a. For raw data, see ITAS data sheets in Appendix S, Exhibit 6; for reduced results, see E&E report in Appendix P.

b. Average results based on individual paired tube analysis for each run. R2 average = 19.6 liters. R3 average volume = 19.5 liters.

c. Only PPL volatiles that were detected are listed. For DLVs of undetected components for paired tubes, see data sheets in Appendix S, Exhibit 6.

TABLE 30. VOLATILE ORGANIC CONCENTRATIONS IN DESORPTION TEST VOST SAMPLES FOR RUNS 2 AND 3 (CONCLUDED)

-
- d. Estimated value, below normal detection level.
 - e. Quantitation mass saturated; actual concentration was higher than reported value.
 - f. Estimated value, tentative identification.
 - g. Questionable identification due to overlap of acetone identification ion with butane identification ion.
 - h. Estimated value, compounds not identified but determined from spectra not to be halogenated.
-

significant volatile compound in the off-gas at NCBC (Reference 1), the actual gas composition cannot be determined except to give a minimum value. For other VOA compounds, the effect of high concentrations of organics on the collection efficiency of the resin and resin/charcoal may also produce low values (e.g., actual gas composition had higher concentrations than indicated). The total loading represented by all the compounds detected was about 200,000 ng/tube, which, based on approximately 2 grams of resin or resin/charcoal per tube, corresponds to a loading of 0.0001 g/g of adsorbent. This is equal to or somewhat lower than the weight capacity loading reported for Tenax[®] (Reference 33). The presence of high concentrations of methylene chloride, etc., and variability in adsorption coefficients for the different types of compounds makes any quantitative interpretation of the VOST results difficult.

i. Ambient Air Filters

The ambient air filter samples for the three runs, totaling 11 samples, were analyzed for the amount of 2,3,7,8-TCDD collected on each filter. None was detected (Table 31; also see the E&E report in Appendix Q). The detection limits have been converted to average air concentrations and range from DLVs of 0.17 to 0.88 pg/m³.

TABLE 31. SUMMARY OF 2,3,7,8-TCDD CONCENTRATIONS IN AMBIENT AIR FILTER SAMPLES

<u>Run</u>	<u>Migration Path Monitored^a</u>	<u>Sampler</u>	<u>Sample Number</u>	<u>Quantity^b (ng)</u>	<u>Average Concentration^{b,c} (pg/m³)</u>
1	Equipment Setup and Testing				
	Upwind control	D	R1-12A	<1.4 ^d	<0.52 ^d
	Offsite	E	R1-12B	<2.4	<0.88
	Offsite control	F	R1-12C	<1.4	<0.55
	Off island	C	R1-12D	<1.1	<0.44
2	Operation of TD/UV Photolysis System				
	Upwind control	D	R2-12A	<0.96	<0.24
	Offsite	F	R2-12C	<1.1	<0.27
	Offsite control	E	R2-12B	<1.5	<0.36
	Off island	C	R2-12D	<0.67	<0.17
3	Decontamination and Demobilization				
	Upwind control	D	R3-12A	<0.75	<0.25
	Offsite	F	R3-12C	<0.94	<0.33
	Offsite control	no sample	--	--	--
	Off island	C	R3-12D	<1.3	<0.30

a. See Figure 36 for layout of air samplers.

b. For raw data, see ITAS data sheets in Appendix R, Exhibit 1; for converted data, see E&E report in Appendix Q.

c. For air volumes applicable to each sampler, see listing in Section IV.D.3.

d. Not detected. Detection limit value shown.

Appendix Q). The detection limits have been converted to average air concentrations and range from DLVs of 0.17 to 0.88 pg/m³.

B. EVALUATION

This section summarizes the pilot-scale test results at JI and presents conclusions for pilot-scale process performance and predicted full-scale process performance. The ability of the process to produce a treated soil that will meet EPA petitioning criteria (40 CFR 260.22) to exclude the soil as a hazardous waste (i.e., delisting) is addressed. Significant problems encountered during the pilot-scale test are identified and discussed in terms of their potential impact on performance of a full-scale system. Process technology issues presented here require some further definition, development, or evaluation to establish a complete final design for a full-scale soil treatment system.

The performances of the individual technologies, thermal desorption and UV photolysis, are discussed separately because these two systems were operated independently and because they can be considered as discrete treatment processes with different technical goals.

1. Soil Thermal Desorption Treatment

a. Dioxin/Furan Reduction

The results from both analytical laboratories showed that all test runs satisfied the project goal that the treated soil PCDD/PCDF congener sum be less than 1.0 ppb. The following lists the average value for the samples analyzed by each laboratory for each test:

<u>Test Run</u>	<u>Average Congener Concentration Sum (ppb)</u>	
	<u>ITAS</u>	<u>Battelle</u>
1	0.344	0.165
2/2A	0.407	0.030
3	0.637	0.883

Therefore, at soil temperatures of 1022 °F, the process was successful in meeting the cleanup criteria goal at an operating rate of up to 209 lb/hr.

Comparison of treated soil and feedstock 2,3,7,8-TCDD and total TCDD results from Tables 8, 9, and 10 shows that substantial removal of dioxin concentrations occurs by the ITC thermal desorption process. Data from both analytical laboratories are shown in Table 32 where applicable.

TABLE 32. TCDD REMOVAL EFFICIENCY IN JI CORAL TREATED BY THERMAL DESORPTION PROCESS

Run	TCDD Removal Efficiency (Percent)			
	2,3,7,8-Isomer Specific		Total Congener	
	ITAS	Battelle	ITAS	Battelle
1	>99.84 ^a	99.94	>99.83 ^a	99.92
2	>99.82 ^a	--	>99.97 ^a	--
3	>99.59 ^a	--	99.57	--

a. Removal efficiency is greater than shown because none was detected in the treated soil. Calculation based on use of the DLV.

The results for Runs 1 and 2 are comparable to the results (99.96 to 99.97 percent) for the desorption test (Run 1) conducted earlier at NCBC (Reference 1). As shown below, a higher feed rate could be used at JI because of the lower 2,3,7,8-TCDD concentration in the feedstock, with the operating temperatures being nearly the same.

Test	Operating Conditions		
	Temperature (°F)	Feed Rate (lb/hr)	2,3,7,8-TCDD Concentration (ppb)
JI Run 1	1049	99	57
NCBC Run 1	1040	31	260

The results show that higher feed rates are possible at the 1049 °F operating temperature while still staying within the 1 ppb cleanup criteria, depending on initial contamination level. Also, the operating temperature is important because Test R3 at 1031 °F showed higher residuals and hence had a lower reduction factor.

b. Organic Compound Reduction

Organic compound removal performance is limited to the reduction of HO constituents 2,4-D and 2,4,5-T because PPL volatiles, semivolatiles, organochlorine pesticides, and PCBs were not detected in the feedstock. These HO constituents were reduced to not-detected limit values of 0.010 ppm. Although the HO constituent analysis in the feedstock was for Test R1 and the analyses for the treated soils were for Tests R2 and R3, a removal efficiency can be calculated by assuming the feedstock in R1 is representative of the whole lot. This is supported by the uniformity of 2,3,7,8-TCDD concentrations measured in the three soil feedstock samples. By also averaging the results of the feedstock sample and its duplicate, the removal efficiencies are at least 99.992 and 99.997 percent for 2,4-D and 2,4,5-T, respectively. These values may be low because treated soil DLVs were used in the calculation. Also, HO analytical difficulties were encountered with the feedstock samples, which suggests the actual concentrations were higher (see discussion in Appendix S, Exhibit 3). The results compare with those found from the thermal desorption testing at NCBC (Reference 1).

Several volatile organic priority pollutants (notably toluene and benzene) were detected in the treated soil samples at very low levels (≤ 1.1 ppm). A variety of isoparaffins were also detected. The presence of these compounds, which are all constituents of the scrubber solvent, is believed to be caused by the contact of recirculated purge gas with treated soil as it discharges from the desorber. The location of the recirculating gas inlet allows exposure of the soil to the constituents of the recirculating gas, which originates in the scrubber. In addition to trace levels of highly volatile solvent constituents contained in the scrubber off-gas, small amounts of such compounds are introduced to this

stream as a result of using Soltrol[®] as a lubricant for the blower seal downstream of the scrubber. Relocation of the recirculating gas inlet and substitution of a less volatile lubricant (or use of a different type of blower) should eliminate the presence of volatile organics in the treated soil.

c. Inorganics

Of five inorganic priority pollutants detected in the feedstock sample (zinc, copper, lead, chromium, and mercury), there were no significant differences in the feedstock and treated soil concentrations. This requires the assumption that the feedstock sample for Test R1 is representative of the whole feedstock lot. This general result was also observed at the NCBC tests (Reference 1).

There were two minor inorganic anomalies. The treated soil samples for Tests R2 and R3 show small amounts of total cyanide (4.3 and 3.5 ppm, respectively); whereas, it was not detected in the feedstock sample for Test R1 (DLV = 0.5 ppm). Similarly, the non-PPL element barium was detected in the treated soil samples for Tests R2 and R3 at 85 and 51 ppm, respectively. In the feedstock sample for Test R1, it was not detected (DLV = 20 ppm). The reasons remain unknown; however, the anomalies cannot be ascribed to analytical difficulties.

d. Hazardous Waste Assessment

The goal of any waste treatment process technology is to have the treated waste no longer considered as hazardous. A petition mechanism (to EPA Headquarters) is described in 40 CFR 260.20 and 40 CFR 260.22 that allows persons to demonstrate that a specific waste from a particular site or generating facility should not be regulated as a hazardous waste under 40 CFR 261. To be excluded, petitioners must show that the waste does not meet any of the listed criteria and must also demonstrate that the waste does not exhibit any of the hazardous waste

characteristics and does not contain any other toxicants at hazardous levels (Reference 34). However, the referenced delisting guidance manual (Reference 34) was not available until after planning for the JI pilot-scale test was well under way and the RCRA RD&D permit application had been submitted to Region IX.

AFESC and EG&G Idaho decided that the ability of the ITC thermal desorption technology to demonstrate the JI treated soil delistability would be assessed within the scope of the planned sample analysis discussed in Section III: PCDDs and PCDFs, organics and inorganics on the PPL, HO constituents 2,4-D and 2,4,5-T, and EP toxicity specified in 40 CFR 261.24. The PCDDs and PCDFs are listed as acutely hazardous (F028) in 40 CFR 261.31. Many of the PPL compounds are also listed as hazardous in 40 CFR 261.33. A complete assessment on delisting would be deferred until the full-scale soil restoration at the JI site. Within the stated limitation, the following assessments are made in relation to the criteria. Closing remarks identify new requirements which were proposed by EPA after the JI tests and would apply for future petition submittals.

(1) Hazardous Waste Characteristics

(a) Ignitability. The objective of examining the ignitability characteristic is to identify substances that either present fire hazards under routine storage, disposal, and transportation, or are capable of contributing to a fire once started. The treated soil does not possess either of these characteristics because it can neither start nor sustain combustion.

(b) Corrosivity. The corrosivity characteristic, defined in 40 CFR Part 261.22, is intended to identify substances that might pose a hazard to human health or the environment because of their ability to:

- o Mobilize toxic metals if discharged in a landfill
- o Corrode handling, storage, transportation, and management equipment
- o Destroy human or animal tissue in the event of inadvertent contact.

In 40 CFR 261.22, EPA specifies two properties that define a corrosive substance: pH and corrosivity toward Type SAE 1020 steel. A substance is defined as corrosive if:

- o It is aqueous and has a pH ≤ 2 or ≥ 12.5 , as determined by a pH meter, using either EPA Test Method 9040 or an equivalent test method approved by the EPA Administrator under the procedure set forth in 40 CFR Parts 260.20 and 260.21.
- o It is a liquid and corrodes steel (SAE 1020) at a rate of >6.35 mm/yr at a test temperature of 131°F , as determined by the test method specified in NACE (National Association of Corrosion Engineers) Standard TM-01-69 as standardized in Method 1110 or an equivalent test method approved by the EPA Administrator under the procedures set forth in 40 CFR Parts 260.20 and 260.21.

These procedures are clearly oriented toward aqueous or liquid substances and, therefore, do not apply to treated soil.

(c) Reactivity. EPA Regulation 40 CFR Part 261.23 defines reactive substances as those that have any of the following properties:

- o Readily undergo violent chemical change

- o React violently or form potential explosive mixtures with water
- o Generate toxic fumes when mixed with water or, in the case of cyanide or sulfide-bearing wastes, when exposed to mild acidic or basic conditions
- o Explode when subjected to a strong initiating force
- o Explode at normal temperatures and pressures
- o Fit within the U.S. Department of Transportation's forbidden explosives, Class A explosives, or Class B explosives classifications.

Because of the extremely inert quality of the treated soil, it does not meet any of these criteria and is, therefore, not a reactive substance.

(d) Extraction Procedure Toxicity

The extraction procedure (EP) is designed to simulate the leaching a substance will undergo if disposed in a sanitary landfill. It is a laboratory test in which a representative sample of waste (100 grams) is extracted with distilled water maintained at a pH of 5 using acetic acid. The EP extract is then analyzed to determine if any of the thresholds established for the eight elements (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver), four pesticides (Endrin, Lindane, Methoxychlor, Toxaphene), and two herbicides [2,4,5-TP (Silvex), 2,4-D] have been exceeded. If the EP extract contains any one of the above substances in an amount equal to or exceeding the levels specified in 40 CFR Part 261.24, the substance possesses the characteristic of EP toxicity and is a hazardous waste.

The EP toxicity test was not actually performed on the treated soil samples because the concentrations of the listed constituents were so low. The measured residual soil concentrations were

used to calculate the maximum (worst case) concentration for each contaminant that could be present in the extract resulting from subjecting the treated soil to the EP toxicity test. These calculated extract concentrations were compared with the criteria levels specified in 40 CFR 261.24 to determine if the treated soil is classified as hazardous based on the EP toxicity characteristic. Table 33 summarizes the measured concentration (average of results for treated soil samples for Tests R2 and R3), calculated maximum concentrations, and EPA criteria. The calculated concentrations are well below the criteria in all cases.

The herbicide, 2,4,5-TP (Silvex; 2,4,5-trichlorophenoxypropionic acid) was not tested, but the HO constituent 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) was and can be used as an upper bound for 2,4,5-TP in this assessment. Results from both treated soil samples (Table 16) showed DLVs of 0.010 ppm. Following the sample calculation in Table 33, a maximum concentration in the EP extract would be 0.0005 mg/L, which is also well below the limit value of 1.0 mg/L.

(2) Acutely Hazardous Waste Assessment

The ITAS and Battelle data presented in this report have established that PCDD/PCDF (F028) can be effectively removed from the tested soil (to less than 1 ppb, 2,3,7,8-TCDD and total tetra-, penta-, and hexa-isomers) by this technology at certain operating conditions. No other compounds were detected in the feedstock that are listed as acutely hazardous in 40 CFR 261.33.

Subsequent to the JI tests in the Federal Register of November 7, 1986 (Reference 13), EPA proposed the following criteria for landfill disposal of materials contaminated with dioxins:

- o Contamination at levels ≥ 1 ppb dioxins requires treatment
- o Treated material < 1 ppb requires a Toxicity Characteristic Leaching Procedure (TCLP) analysis (Appendix J to 40 CFR 268)

TABLE 33. CONCENTRATIONS OF ELEMENTS IN TREATED SOIL EP EXTRACT ASSUMING COMPLETE EXTRACTION

Element	Concentrations in Treated Soil (mg/kg) ^a	Maximum Concentration in EP Extract (mg/L)	EPA Threshold Limitation (mg/L)
Arsenic	1.1	0.055 ^b	5.0
Barium	68	3.4	100.0
Cadmium	<0.2	<0.01	2.0
Chromium	7.5	0.38	5.0
Lead	8.8	0.44	5.0
Mercury	<0.02	<0.001	0.2
Selenium	<1.0	<0.05	1.0
Silver	<0.6	<0.03	5.0
Endrin	<0.016	<0.0008	0.02
Lindane	<0.008	<0.0004	0.4
Methoxychlor	<0.081 ^c	<0.004	10.0
Toxaphene	<0.160	<0.008	0.5
2,4-D	<0.01	<0.0005	10.0
2,4,5-TP (Silvex)	NA ^d	--	1.0

a. See Table 14 for average inorganic concentrations of treated soil samples for Tests R2 and R3, Table 13 for pesticide and PCB DLVs, and Table 16 for herbicide DLVs.

b. Sample calculation for arsenic in EP extract assuming complete extraction:

$$100 \text{ gram sample} \times 1.1 \text{ mg/kg} = 0.11 \text{ mg}$$

0.11 mg of arsenic dissolved in 2 L of solution results in a concentration of:

$$\frac{0.11 \text{ mg}}{2\text{L}} = 0.055 \text{ mg/L}$$

c. Data from Appendix S, Exhibit 2.

d. NA means not analyzed.

- o Treated material <1 ppb requires a Toxicity Characteristic Leaching Procedure (TCLP) analysis (Appendix J to 40 CFR 268)
- o Material meeting these criteria can be disposed of in a Class C landfill or be delisted.

The testing at JI has demonstrated that the first criterion for coral can be met after treatment. TCLP remains to be done and represents a limitation on showing that the final criterion can be met.

(3) Hazardous Constituents Review

Analysis of soil samples was limited to those compounds or elements listed as priority pollutants (Appendix I) and HO constituents 2,4-D and 2,4,5-T. Of the organics, only 2,4,5-T (listed as a toxic hazardous waste in 40 CFR 261.33) and 2,4-D (listed in Appendix VIII of 40 CFR 261) were detected in the soil feedstock. Treated soil sample results showed that the process removed these two herbicides to nondetectable concentrations well below 1 ppm.

Of the PPL inorganics, two were detected above 1 ppm in the feedstock sample that are listed in Appendix VIII (lead, chromium); however, the concentrations were quite low (<10 ppm). Concentrations in the treated soil samples were similar. Although not detected in the feedstock sample (DLV = 20 ppm), barium, which is listed in Appendix VIII, was shown at concentrations of 85 and 51 ppm in the treated soil samples. Also total cyanide, which is listed in Appendix VIII, was not detected in the feedstock sample (DLV = 0.5 ppm), but was detected in treated soil samples at concentrations of 4.3 and 3.5 ppm. As evaluated by the EP toxicity analysis, these concentrations of inorganics are low and should be considered not hazardous.

(4) Concluding Remarks

The following conclusions can be made relating to the ITC thermal desorption process producing a delistable waste from the HO-contaminated coral. Because the treated soil is not corrosive, ignitable, or reactive and because it passes the requirements for the EP toxicity test, the requirements of 40 CFR 261.21-261.24 can be satisfied. The acute hazardness of the contaminated coral can be reduced to concentrations of dioxins that are less than the 1 pph in the EPA proposed rules for landfill disposal of dioxin-contaminated material. The concentrations of 2,4-D and 2,4,5-T, the only organics detected in the feedstock above 1 ppm, were removed to nondetectable levels well below 1 ppm in the treated soil. Inorganics listed in Appendix VIII were found at sufficiently low concentrations that the EP toxicity results had substantial margins.

Because the analysis screening was limited to the PPL and principal HO constituents, it is possible that there are other listed organic compounds in the soil at the former HO site. Further screening is needed to determine what additional compounds would require analysis. As previously stated, TCLP analysis needs to be done to satisfy one criterion from the proposed landfill disposal criteria. One other EPA proposed requirement from the Federal Register of November 27, 1985 (Reference 35) is an evaluation of the JI site using the EPA vertical and horizontal spread (VHS) model. Although not sufficient, the data from the process pilot-scale testing support the treated coral being delisted if full-scale restoration of the site employs the ITC thermal desorption technology. Because the full requirements for delisting the material with EPA are uncertain, application of any technology must be judged against the regulations that apply at the time. Before full-scale restoration at the JI site, it would be prudent to reach delisting agreement with EPA Headquarters before field operations begin.

e. Off-Gas Treatment Effectiveness and Air Emissions

The results of the analysis of vent carbon samples and gas samples presented in Section V.A.4.g were used to estimate the composition and corresponding quantities of chemicals contained in the scrubber off-gas before and after carbon adsorption. Table 34 presents the calculated quantities of HO-related compounds found in the vent carbon. Table 35 presents the calculated quantities of the HO-related compounds in the process vent (after adsorption) based on the gas sampling results. Methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) values are included in these tables, although they are not considered process-related. The chloroparaffin values represent a minimum since chloromethane, the predominant constituent, was above the quantitation limit, as discussed in Section V.A.4.g. Solvent-related isoparaffin compounds were also observed in the vent carbon, but their quantities were not calculated.

Table 36 converts these calculated results to mass loadings to and from the adsorber based on hourly rates and unit ratios, to project process emissions from a larger-scale facility. It was assumed that all organics contained in the carbon from both the primary and the secondary adsorbers were contained in the scrubber off-gas; methylene chloride and Freon 113 were not considered in this assessment. Recognizing that quantitative results are likely to be low because of the saturated condition of the VOST samples, projected unit ratio emissions were also calculated at a factor of ten times the calculated values for volatile compounds. For Test R3, this resulted in an estimated total VOA emissions factor of about 15 mg/kg of soil treated. Considering a 100 tons per day, full-scale desorber operation, the corresponding total daily emissions would be 0.3 to 3 pounds, depending on which emission factor is used. Using the emission factors for 2,4-D and 2,3,7,8-TCDD from Table 36, the calculated daily emissions for the same facility would be less than 3 mg and 0.2 mg, respectively. Since these compounds were not detected in the process emission sample, these values are worst case and do not accurately represent the potential for emission of these compounds.

TABLE 34. CALCULATED QUANTITY OF ORGANIC COMPOUND FOUND IN VENT CARBON

Compound	Quantity ^{a,b} (mg)		
	Primary Filter ^c	Secondary Filter	Total
2,4-D	<0.03	<0.03	<0.06
2,4,5-T	<0.03	<0.03	<0.06
2,3,7,8-TCDD	<0.0003	<0.0004	<0.0007
Total tetra-hexa PCDD/PCDF	<0.0054	<0.0024	<0.008
Chlorophenols	5.4	2.4	7.8
Phenol	6.9	<5.7	<12.6
Chloroparaffins	7.5	2.4	9.9
Aromatics	1.8	<0.015	1.8
Methylene chloride ^d	2,250	2,100	4,350
1,1,2-trichloro-	81,000 ^c	87,000	168,000
1,2,2-trichloroethane ^d			

a. Assume 3 kg of carbon in each adsorber.

b. See Appendix R, Exhibit 1, for PCDD/PCDF data sheets (Samples R3-09, R3-09A, R1-3-10). See Appendix S, Exhibit 2, for remaining data sheets.

c. Average of analytical results for R3-09 and R3-09A was used except for 1,1,2-trichloro-1,2,2-trifluoroethane for which the higher result was used.

d. Both compounds were present as the result of contamination.

TABLE 35. CALCULATION OF ORGANIC COMPOUNDS FOUND IN PROCESS VENT

Compound	Quantity in Sample (mg)			Sample Gas Volume (l)			Gas Concentration (mg/L)			Quantity in Process Emission (mg/hr)		
	R2	R3	NA	R2	R3	NA	R2	R3	NA	R2	R3	NA
2, 4-D	NA	NA	NA	--	--	--	--	--	--	--	--	--
2, 4, 5-T	NA	NA	NA	--	--	--	--	--	--	--	--	--
2, 3, 7, 8-TCDD	<0.001 ^a / _{<0.001^b}	<0.001 ^a / _{0.001^b}	<0.001 ^a / _{0.001^b}	7300 ^a / _{5200^b}	9900 ^a / _{4300^b}	9900 ^a / _{4300^b}	<0.33 x 10 ⁻⁶	<0.34 x 10 ⁻⁶	<2.5 x 10 ⁻⁶	<2.5 x 10 ⁻⁶	<2.2 x 10 ⁻⁶	<2.2 x 10 ⁻⁶
Total tetra-hexa PCDD/PCDF	<0.006 ^a / _{<0.009^b}	<0.013 ^a / _{<0.007^b}	<0.013 ^a / _{<0.007^b}	7300 ^a / _{5200^b}	9900 ^a / _{4300^b}	9900 ^a / _{4300^b}	<2.5 x 10 ⁻⁶	<3.0 x 10 ⁻⁶	<19 x 10 ⁻⁶	<19 x 10 ⁻⁶	<20 x 10 ⁻⁶	<20 x 10 ⁻⁶
Chlorophenols	<20	<20	<20	5200	4300	4300	<0.004	<0.005	<0.029	<0.031	<0.031	<0.031
Phenol	<10	<10	<10	5200	4300	4300	<0.002	<0.002	<0.014	<0.015	<0.015	<0.015
Chloromethane	>14	>50	>50	20	20	20	>0.7	>2.5	>5.4	>16	>16	>16
Other chloroparaffins	5.1	2.0	2.0	20	20	20	0.26	0.1	2.0	0.65	0.65	0.65
Methylene chlorided	>36	>64	>64	20	20	20	>1.8	>3.2	>14	>21	>21	>21
1,1,2-trichloro-1,2,2-trifluoroethane ^{d,e}	>28	>17	>17	20	20	20	>1.4	>0.85	>11	>5.6	>5.6	>5.6
Aromatics	0.013	0.030	0.030	20	20	20	0.0007	0.002	0.005	0.01	0.01	0.01
Isoparaffins ^f	77	40	40	20	20	20	3.9	2.0	31	13	13	13

a. Volume of gas sampled for particulate filters was the entire process vent emission flow for the prescribed sampling period.

b. Volume of gas sampled through XAD trap and impingers was controlled.

c. Volume of gas sampled for each VOST tube was approximately 20 liters.

d. These compounds originated from contaminated carbon used in the process vent adsorber units upstream.

e. Includes related compounds (e.g., trichlorofluoromethane).

f. Includes unknowns (unhalogenated) and acetone, which was questionably identified due to interferences.

TABLE 36. CALCULATED PROCESS EMISSIONS BEFORE AND AFTER VENT CONTROL (CARBON ADSORPTION)

Compound	Quantity ^a (mg/hr)		Quantity (mg/kg soil)	
	To Adsorber ^b		To Atmosphere ^c	
	R3	R2	R3	R2
2,4-D	$<8,000 \times 10^{-6}$	NA ^d	$<800 \times 10^{-6e}$	--
2,4,5-T	$<8,000 \times 10^{-6}$	NA	$<800 \times 10^{-6e}$	--
2,3,7,8-TCDD	$<100 \times 10^{-6}$	$<2.5 \times 10^{-6}$	$<2.2 \times 10^{-6}$	$<0.7 \times 10^{-6}$
Total tetra-hexa PCDD/PCDF	$<1,100 \times 10^{-6}$	$<19 \times 10^{-6}$	$<20 \times 10^{-6}$	$<6.4 \times 10^{-6}$
Phenols/chlorophenols	2.8	<0.043	<0.046	<0.002
Chloroparaffins	>18.1	>7.4	>16.7	>0.083
Aromatics	0.25	0.005	0.01	57×10^{-6}
Isoparaffins	6,200	31	13	0.31
Total	6,204	38	30	>0.44
			270	>1.31

a. All values with less than sign (<) are maximum or worst-case values since they are based on summation of detection limits.

b. Values determined from total carbon loadings of primary adsorber for R3 only plus secondary adsorber for all three desorber tests allocated over the total test period (e.g., 7.25 hours).

c. Values determined directly from sampling results; assume 100 percent sampling efficiency.

d. NA means not analyzed.

e. Assumes 90 percent removal by carbon adsorber; no analysis was performed.

TABLE 37. CALCULATED QUANTITY OF SELECTED HERBICIDE ORANGE COMPOUNDS
CONTAINED IN SOIL TREATED DURING THERMAL DESORPTION TESTS

Compound (units)	Quantity			
	R1	R2	R2A	R3
Soil (kg/hr)	45	88	95	23
2,4-D (g/hr)	1.10	2.16 ^a	2.33 ^a	0.56 ^a
2,4,5-T (g/hr)	1.58	3.08 ^a	3.33 ^a	0.81 ^a
TCDD (µg/hr)	2,080	3,620	3,910	1,100
PCDD (µg/hr)	<7.7 ^b	4.6	5.0	<0.8 ^b
HCDD (µg/hr)	<15	<25 ^b	<27 ^b	<14
TCDF (µg/hr)	<13	48	52	<2.8
PCDF (µg/hr)	<7.2	6.1	6.6	<5.5
HCDF (µg/hr)	<12	<5.2	<5.6	<12

a. Analysis was not performed. Results of analysis of R1 feed soil were used to calculate these values.

b. Not detected. Detection limit value shown.

In assessing these projected emissions, an improvement in carbon adsorber performance containing uncontaminated carbon should decrease the quantity of all the identified compounds in the process vent. Chloromethane, because of its extremely high vapor pressure, would be the largest potential emission.

Scrubber performance for HO-related compounds was evaluated by comparing the mass loadings in the scrubber off-gas to the amount of HO-related compounds in the soil processed. Table 37 presents the hourly rate of HO-related compounds contained in the soil. Comparison with the

values in Table 36 indicates a scrubber removal efficiency greater than 99.995 percent for 2,3,7,8-TCDD and greater than 99.95 percent for total tetra-hexa PCDD/PCDF isomers. The removal efficiency for 2,4-D and 2,4,5-T and the corresponding chlorophenol decomposition products was 99.98 percent. Considering that all adsorber performance was calculated by comparing the values in Table 36, actual removal efficiencies for PCDD/PCDF could not be determined because no isomers were detected in the spent vent carbon.

Removal efficiencies for phenols/chlorophenols, aromatics, and isoparaffins were calculated as greater than 98, 96, and 99.8 percent, respectively. Removal efficiencies for chloroparaffins were poor because of the high levels of chloromethane found in the VOST samples; this was similar to the NCBC results (Reference 1). Adsorption performance for selected compounds would be expected to be influenced by the presence of high levels of other compounds in the solvent or the degree of maximum solubility of the compound in the solvent at the operating temperature, although compound selectivity is also important in adsorption treatment of multicomponent gas streams.

f. Scrubber Filtered Solids Waste

The PCDD/PCDF concentrations for the scrubber filtered solids sample (R1-3-06) discussed in Section V.A.4.e clearly show the material is a hazardous waste. For example, the 2,3,7,8-TCDD concentration was 232 ppb. There are several solutions to this problem for full-scale operation. The amount of particulate collected in the scrubber solvent can be greatly reduced by use of a dry collector (e.g., high-efficiency cyclone) upstream of the scrubber. The solids from the dry collector could be easily recycled to the desorber if determined to be contaminated. Likewise, the solids filtered from the solvent could be periodically recycled by blending with soil feedstock. Otherwise, this sludge would be packaged as waste material for shipment to a dioxin-qualified incinerator disposal site, provided there is one RCRA-permitted. If there is no dioxin disposal operation permitted at the time, continued use of the interim

hazardous waste storage in Bunker 788 would be a temporary solution. Even if the first is followed, it is likely that some small residual scrubber solids waste would occur at the end of the remedial action when the field setup is shut down.

g. Wastewater Treatment Efficiency and Effluent Quality

No testing of aqueous condensate treatment was conducted. Evaluation of the analytical characterization results discussed in Section V.A.4.f indicates that treatment would be required to reduce the phenolics and remove the 2,3,7,8-TCDD to meet typical EPA effluent limits for these regulated pollutants. Treatment to reduce the total organic content would also be required. The required degree of treatment and corresponding effluent quality will depend to some extent on where the treated effluent is to be discharged and the potential impact of the residual pollutants on the receiving waters. The volume of aqueous condensate for the thermal desorption process is very small, which means the quantity of residual pollutants discharged at a given effluent concentration limit (e.g., mg/L) is very low. For example, a full-scale process treating 10 tons per hour of contaminated soil having a moisture content of 10 percent would generate only approximately 5,200 gallons per day of condensate. A residual phenol concentration of 1 mg/L would represent a daily discharge of only about 22 grams of phenol. Wastewater treatment requirements are discussed further in Section V.B.3 as an outstanding technical issue.

2. Solvent UV Photolysis Treatment

a. Dioxin/Furan Reduction

Substantial reduction of PCDD/FCDF concentrations in scrubber solvent was achieved during UV photolysis test (Table 17 and Figure 38). However, the sum of the six isomer classes was considerably above the project goal of 1 ppb, as shown by data from both analytical laboratories. The 2,3,7,8-TCDD concentration for the sample was less than

1 ppb and is an achievement because of its toxicological acuteness. Removal efficiency for this isomer was at least 99.90 from ITAS data and 99.94 percent from Battelle data (Table 17). The removal efficiency varied (90 to >99 percent) for the different PCDD/PCDF congeners; all were lower than for 2,3,7,8-TCDD.

Increased reduction of PCDD/PCDF congeners to a concentration of less than 1 ppb would require longer reaction time or higher light energy. This could be critically important if there is no RCRA dioxin-permitted facility to dispose of the residual solvent. A full-scale integrated treatment facility must consider another factor. In a continuously operating thermal desorption/UV photolysis process, the photolysis system must treat the quantity of combined HO constituents entering with the soil feed. The treatment removal efficiency and residual levels of HO constituents for the recycled scrubber solvent must only be sufficient to account for the HO load to the desorber and reach concentration levels that are acceptably low. The EPA proposed standard of less than 1 ppb PCDD/PCDF for landfill disposal would appear to be a concentration level to meet.

b. Organic Compound Reduction

UV photolysis treatment of the contaminated scrubber solvent to remove HO-related organics present (e.g., 2,4-dichlorophenol, 2,4,5-trichlorophenol, phenol, 2-chlorophenol) was partially successful. The 2,4-dichlorophenol and 2,4,5-trichlorophenol were not detected in the treated solvent, with DLVs of 1.0 and 5.0 ppm, respectively. The 2-chlorophenol was reduced to 0.25 ppm. However, the phenol was shown to increase from untreated sample concentrations of 12 ppm (Sample R2-03) and 8.9 ppm (Sample R3-03) to 37 and 78 ppm in the treated sample (R1-04) and its field duplicate (R1-04A), respectively. Actual removal efficiencies for 2,4-dichlorophenol and 2,4,5-trichlorophenol could not be determined because the final concentration was below the analytical detection limit. Using the DLVs, removal efficiencies were calculated to be >99.5 and >97.8 percent, respectively. Chlorophenol appeared to be slower in

reaction rate, which may have been a result of being produced as an intermediate during the dechlorination of the di- and trisubstituted compounds. Methylphenols were subject to photolysis at a rate comparable to the di- and trichlorophenols, whereas phenol concentrations actually increased as a result of the dechlorination reactions. The photolysis results were similar to the NCBC test results (Reference 1), although the initial concentration of 2,3,7,8-TCDD was ten times higher for the JI tests. The higher concentration was more representative of a full-scale integrated TD/UV photolysis process facility.

c. Inorganics

Unlike the NCBC results (Reference 1), the inorganic concentrations in the treated solvent were exceedingly low (Table 21). The untreated scrubber solvent concentrations were also low. This can probably be attributed to two factors. The inorganic concentrations in the JI soil feedstock were low compared to those at NCBC. Also, initial metal surface cleaning of the entire solvent system had already occurred at NCBC. Also, pump repair at NCBC apparently prevented excessive wear at JI.

d. Organic Waste Residues

No analysis was performed to determine what reaction products were formed from photochemical decomposition of the chlorophenols and PCDD/PCDF congeners. As discussed in Section II.B.2, likely products are unchlorinated phenolic tars, which have limited solubility in Soltrol[®]. During the pilot-scale tests, the solvent was not processed to remove soluble or insoluble reaction products. The insoluble residues were removed from the reactor components by manual cleaning with isopropyl alcohol and/or acetone. For a full-scale continuously operating system, small amounts of organic residues will be generated routinely and process steps will be required for separation and removal of these reaction products to maintain reasonable reactor efficiencies.

e. Process Air Emissions and Waste Water Discharges

Normally, no off-gases or aqueous wastes will be produced during the photolysis operation. No measurements were made of the process vent during the pilot-scale tests; and no aqueous material, which would be apparent as a discrete phase, was observed.

3. Problems and Resolutions

During field testing, two process problems occurred that affected the operation of the tests and the results obtained. Each of these was related to mechanical difficulty rather than technological failure, and the incorporation of appropriate equipment design features for a large-scale system would effectively avoid these problems.

a. Soil Feeding

The physical and chemical composition of the crushed soil (coral or calcium carbonate) at JI resulted in very poor flow characteristics. Soil loaded to the desorber feed hopper tended to pack and "bridge," and repeated manual probing of the hopper contents with a rod was required to maintain flow into the desorber feed screw conveyor. The soil was air-dried but had higher moisture content than the air-dried soil at NCBC (e.g., 4 percent versus 2 percent).

The experience during the NCBC and JI pilot-scale tests was not necessarily translatable to performance of a full-scale system because the equipment clearances were so small, necessitating drying the soil and crushing the soil to a relatively small size. Comparatively, JI coral (after crushing) had poorer flow characteristics than the NCBC cement-stabilized soil and required constant attention to force material to move from the feed hopper to the screw conveyor. This is attributed to coral particle shape and/or agglomeration caused by hydration of the calcium carbonate surfaces exposed during the grinding. Flow of both NCBC and JI soil through the desorber was not a problem.

For a large-scale desorber, soil feeding systems must be designed to avoid flow problems. Conventional equipment is available for feeding a wide variety of solid materials with different flow characteristics. Larger equipment will also allow larger particle sizes, and a coarser feedstock is expected to have better flow properties.

b. Particulate Entrainment

The original design of the pilot-scale thermal desorber and solvent scrubbing unit assumed that a very small fraction of fine soil particulates would be carried by the purge gas from the desorber into the solvent recirculation loop. After testing at NCBC, modifications were made to the off-gas transfer and scrubbing system to handle larger particulate loadings. These changes included a cyclone-like chamber to separate entrained soil particles before they were contacted by the scrubber solvent. Larger filters were also installed in the solvent recirculation system to remove particulate collected by the scrubber. These changes improved operation of the scrubbing system at JI. However, during Tests R2 and R2A when the soil processing rate was double the previous maximum used at NCBC, frequent changes of the filter media were required once the dry separator became full. Despite these much higher operating rates, the total measured quantity of particulate entrained from the desorber was determined to be less than 1 percent of the soil feed, which was comparable to NCBC.

Control of particulate in a full-scale system could be accomplished by incorporating conventional dry separators (e.g., cyclones) and properly sized clarifier and filtration units for the solvent scrubbing system. The quantity of particulate will be a function of the superficial gas velocity within the desorber (which results from evaporated moisture and purge gas flow), the particle size distribution of the thermally processed soil, and the degree of disturbance of the soil within the desorber. A wide range of entrainment rates might be experienced, and design and operating criteria should address this issue. Soil particulate

collected in a full-scale system can be recycled to the desorber and does not represent a process waste discharge.

4. Outstanding Technical Issues

The pilot-scale process used at JI was designed to answer the principal technical questions regarding performance of the three major process steps: desorption, scrubbing, and photolysis. Secondary process steps not included in the demonstration were treatment and recycling of photolyzed solvent and treatment of aqueous condensate, which was originally planned but not accomplished. These process steps need to be further defined and demonstrated before design of a complete full-scale soil treatment facility. These issues were identified in the NCBC report (Reference 1) and are repeated below with some updating.

a. Solvent Treatment

The thermal desorption/UV photolysis process concept described in Section II.A is based on recycle of the scrubbing solvent. The reaction products of photolysis, including insoluble and soluble components, must be separated to ensure sustained reactor efficiency and to maintain good scrubber performance. The photolysis and treatment of scrubber solvent would be performed on only a portion (purge) of the scrubber solvent recirculation stream; the photolyzed and treated purge solvent would be recycled to the scrubber solvent system. A number of conventional treatment processes could be utilized to accomplish this separation, including gravity settling, centrifugation, filtration, distillation, extraction, adsorption, or some combination of these unit operations. The residues resulting from such a separation would require ultimate disposal as a hazardous waste unless the characteristics were suitable to meet delisting criteria. Selection, definition, and design of a solvent treatment process would be based on existing technical and engineering information and data for treatment of comparable organic solutions plus laboratory bench-scale experiments using actual photolyzed solvent containing the reaction products of 2,4-dichlorophenol and

2,4,5-trichlorophenol. Section VI develops preliminary engineering definition and costs for a preferred solvent treatment process and projects the organic residue quantities and characteristics.

b. Water Treatment

The aqueous condensate separated from the solvent will contain soil particulate and soluble and insoluble organic compounds originating from the HO and solvent. PCDD/PCDF congeners present would be expected to be primarily dissolved in entrained solvent droplets or associated with soil particulate. The solubility of these compounds, which is extremely low in pure water, may be elevated by the presence of soluble organic constituents such as chlorophenols. Analysis of the filtered condensate collected at JI indicates that 2,3,7,8-TCDD is present at concentrations much higher than theoretical solubility and that total soluble organic content is relatively high.

To enable discharge of the aqueous condensate within normal regulatory requirements, a treatment system must effectively separate the entrained solvent and particulate and remove dissolved chlorophenols or other regulated pollutants. The design of a full-scale water treatment system can be developed using existing technical performance data for similar wastewater characteristics. ITC has conducted laboratory and field tests of wastewater treatment processes for removal of soluble and insoluble chlorophenols, hydrocarbons, and PCDD/PCDF congeners which can be coupled with literature data to provide a system design that would be expected to meet anticipated regulatory discharge criteria. Cost projections in Section VI include a condensate treatment system designed and based on such information.

SECTION VI

COST ESTIMATING FOR FULL-SCALE APPLICATION OF THERMAL DESORPTION/UV PHOTOLYSIS TECHNOLOGY

This section presents the cost estimate to transport equipment and personnel to and from JI and to perform the excavation, soil preparation, and treatment of 2,3,7,8-TCDD-contaminated soil at the former HO storage site. As stated in Section I.B.3, the site covers 4.33 acres. One estimate of the contaminated soil volume was 17,600 yd³, representing a depth of about 30 inches. Based on measured density of JI soil,* the equivalent tonnage calculates to about 20,400 tons. For ease of comparison with the cost analysis in the NCBC report (Reference 1) for the same technology, the tonnage for remedial action is assumed to be 20,000 tons, which was the reference case in the NCBC analysis. Holding to the soil density used, the equivalent excavated volume would be about 17,200 yd³. Treatment of the contaminated soil is assumed, using the TD/UV photolysis process developed by the IT Corporation.

Generic costs are taken from the NCBC report (Reference 1), where applicable, for the assumed JI remedial action. Overwater transportation and unique JI conditions required new cost estimates. This cost preparation was made by the Cost Estimating Group at EG&G Idaho with consultation with ITC personnel, the Department of Energy representative at JI, and others.

Again for ease of comparison with the NCBC cost estimate data, the format for the cost estimate has been retained. Accordingly, costs are separated into four basic categories:

*The "JI as-received" measured density for Sample 4761 is 86 lb/ft³ (see Table 16 in Volume III of the NCBC report--Reference 1). All weights are presented as excavated condition.

1. Common remedial costs
2. Common site operating and monitoring costs
3. TD/UV photolysis process setup/removal costs
4. TD/UV photolysis process operating and maintenance costs.

These categories are explained as follows. Many of the costs identified in this estimate are common to any thermal treatment alternative, whether it is TD/UV photolysis, rotary kiln, infrared heat, etc. These costs are dictated by site characteristics, regulations, physical handling, and other constraints, and are largely independent of the treatment process. These costs are grouped into the first two categories: common remedial costs and common site operating and monitoring costs. Transportation costs for equipment in these categories are included because of the site remoteness and unavailability of the equipment at the island. The remaining two categories are process-related. Category 3, process setup, includes the transportation of the process equipment to and from the site, setup, checkout testing, a trial burn, standby following the trial burn, tear down, decontamination, and removal of the process equipment. The last category (4) then covers the production soil treatment. These categories are discussed in more detail in Section VI.C.2.

The cost estimating procedure for common costs (1 and 2) is similar to that normally used by CH₂M Hill, Inc., and relies on cost history obtained at recent excavations of TCDD-contaminated soil in the state of Missouri. A number of these costs are based on input by CH₂M Hill for another technology at a generic site. EG&G Idaho revised this input for NCBC conditions, and it was reported in Reference 2 and further used in support of the ITC developed TD/UV photolysis technology at NCBC (Reference 1). The process-related costs (3 and 4) are primarily from ITC input for the NCBC report. These estimates are based on engineering design, capital cost estimating, and operating cost projections performed for numerous thermal and chemical-physical treatment system for hazardous

waste disposal and remedial action at contaminated sites. In addition, ITC was the technical and operating contractor for the first successful trial burn in 1985 of EPA's mobile incinerator system, which treated dioxin-contaminated soil in Missouri (Reference 36).

To present these cost data, this section consists of six parts:

1. Remedial action approach
2. Scaleup technical basis
3. Cost-estimating approach and basis
4. Cost estimate
5. Sensitivity analysis
6. Comparison with NCBC reference case.

Because the final cost estimate was prepared by EG&G Idaho, there is no independent validation.

A. REMEDIAL ACTION APPROACH FOR REFERENCE CASE

1. Overall Remedial Description

At the site, 20,000 tons of TCDD-contaminated soil will be excavated and transported to a storage area for treatment. The soil will be fed through the soil preparation plant at a rate of about 215 tons/day to match the TD/UV photolysis process treatment rate. Both facilities are intended to operate around the clock on a 7-day work week and to be manned by four rotating shift crews. Equivalent TD/UV photolysis feed rate on this basis, assuming about 90 percent operating factor overall, is 10 tons per hour. Several days' worth of feedstock (400 tons) is planned to be excavated and stored onsite as a buffer to provide for continuous operation

of the TD/UV photolysis process. After TD/UV photolysis process treatment, the treated soil will be sampled and temporarily stored in secured quarantine areas pending successful analysis before replacement to the same area from which it was excavated. The bottoms of the excavated areas will be sampled for analysis to show that restoration criteria are met and further excavation is not needed. This is done before any released soil is backfilled into the excavation.

The TD/UV photolysis process equipment and soil feedstock preparation facility will be contained within a process operating area of about 100 by 200 feet. It is assumed that ITC (or other qualified contractor having necessary TD/UV photolysis process equipment and technology) will be responsible for the mobilization, operation, and demobilization of all equipment associated with feedstock preparation and soil treatment. The site preparation for the process operating area and all activities outside this area are assumed to be the responsibility of USAF or its agent.

Trial burn results, subsequent process operations data, and analysis data from treated material samples and excavation bottom samples will be provided from the restoration project for subsequent petitioning to EPA Headquarters to exclude the site as hazardous (i.e., delist).

2. Assumed Site Conditions

The reference waste site is assumed to be the HO-contaminated area at JI. Johnston Island, oriented NE-SW and largest of three islands of the atoll, lies near the heart of the trade wind zone in the east-central tropical Pacific about 717 nautical miles southwest of Honolulu, Hawaii. The maximum elevation is 20 feet. Climatology for JI is presented in Appendix V and summarized in the following paragraphs.

Surface trade winds are dominant year around. Winds from between northeast and east (inclusive) are experienced 62 percent or more of the time in every month, with an annual average of 85 percent (10-year

average). There are two seasons. The winter season extends from December through March. During this season, light variable winds are most frequent and tendency from the trade wind direction is least.

The winter season has more rain, with a mean of 11 inches for the 4 months. These rains are frequently associated with organized disturbances, such as easterly waves, the passage of troughs aloft, or weak cold-front passages. During the summer season (between April and November), rainfall is dominantly in the form of trade wind showers, with a mean average of 15 inches over the 8 months. However, in April and September to November, identifiable organized disturbances are common, and these may bring very heavy rains, as when a tropical depression or tropical storm passes by. JI has experienced hurricanes infrequently.

JI temperatures are slightly higher during the summer season, with a mean average temperature of 80 to 81 °F between July and October. Mean average temperature during the winter season is between 76 and 78 °F. The mean diurnal range is 7 to 8 °F, with little seasonal variation. Humidities are high during all times of the year.

The original coral atoll was 42 acres, but extensive dredging and filling of the original shoreline have increased the size to its present 625 acres. The former HO storage site, which consisted of 10 acres, is at a maximum point downwind on the island and is composed entirely of coral material. The terrain is flat (see Figure 6). The island has no fresh water lens, and the underlying seawater flow (approximately 7 feet beneath the surface) is from NE to SW. Therefore, the intake for the island's fresh water desalinization unit is 10,000 feet up-current from the former HO storage site. Subsurface seawater flow from the former HO storage site is seaward because the site is at the extreme southwest point of the island.

B. SCALEUP TECHNICAL BASIS

1. Scaleup Size

a. Thermal Desorber

ITC has used the recommendations of experienced manufacturers of indirect-heated thermal desorber equipment to project the operating capacity of the mobile full-scale facility for use at JI, NCBC, or similar sites. Specific engineering evaluation and preliminary design have established that the thermal duty and volumetric flow rate of large rotary desorber units processing soil at temperatures and residence times compare to conditions used successfully by the pilot-scale desorber. The scaleup size selected for this cost evaluation has been demonstrated on many comparable or larger-scale systems processing various types of solids in the mining, chemical, and related industries. The scaleup size is 10 tons/hour of soil, containing 10 percent moisture; moisture of 20 percent will reduce the capacity between 20 and 30 percent. This rate represents a scaleup factor of about 100 to 400 times the rate demonstrated at JI during the pilot-scale tests, depending on which test feed rate is considered.

The time-temperature data from the JI tests were evaluated to establish the required temperature profile of the soil within the full-scale unit and the corresponding heat transfer capacity. A volumetric loading for the full-scale unit will be comparable to the pilot-scale operating experience and is typical of many types of direct-fired and indirect-heated rotary devices, such as kilns. The diameter and length were chosen to be as large as physically possible to still allow transport by truck. The heated section of the full-scale unit will provide up to 30 minutes residence time at the base case of 10 tons/hour. Rotational speed is much slower for the large unit as a result of the larger diameter.

b. Off-Gas Rates and Scrubbing Requirements

The off-gas rate for the full-scale desorber is based on material balance calculations, assuming soil feed containing 10 percent moisture and an inert gas purge rate of 75 scfm (providing a minimum gas velocity comparable to that experienced during the pilot-scale tests). Maximum superficial gas velocity within the desorber (at 10 percent moisture) would be 2.5-5 times higher than was experienced during the pilot-scale tests, because the soil moisture of the prepared (air-dried) JI soil was only about 2 to 4 percent, and water vapor constitutes the majority of the off-gas. A soil carryover rate of 1 percent of the feed, comparable to the pilot-scale experience, is considered reasonable for a scaleup basis. Incorporation of a dry particulate separator in the full-scale off-gas system would reduce the amount of solids collected by the scrubber solvent. The collected particulates would be returned to the desorber feed system for recycling and not represent a process waste.

The scrubber for the full-scale unit is sized, based on gas flow and solvent flow, using standard heat and material balance calculations and design parameters for scrubber systems. Solvent flow would be sufficient to remove the maximum heat load of the off-gas while maintaining an outlet (scrubber) gas temperature of approximately 41 °F, which is somewhat lower than the pilot-scale conditions used at JI. Solids collected by the scrubber solvent would be removed from the scrubber system by filtration. The filter solids will be recycled to the desorber feed system and metered in with soil feedstock. This recycled material is projected to represent less than 0.5 percent of the total feed rate.

c. Emission Control System

Based on the concentration of organic compounds detected in the samples of activated carbon from the pilot-scale vent control adsorbers and using representative performance and design criteria for such volatile organic compound (VOC) control technology, a full-scale emission control system was defined. In addition to adsorption, a standard high-efficiency

particulate filter is included in the full-scale design to ensure particulates are not emitted. A VOC composition was derived from the evaluation of the vent carbon data in Section V.B.1.e, vapor pressure data, and projected vent gas flow. A total VOC concentration of 1500 ppm and carbon equilibrium capacity (loading) of 0.04 lb organic/lb carbon were used to calculate carbon adsorber size and carbon consumption. Noncondensable gas volume discharged through the emission control unit was estimated to be 125 scfm, or about one-half the flow, based on scaling gained from experience during the JI pilot-scale tests. This reduction assumed lower relative air leakage (infiltration) for a large desorber system.

d. Photolysis System

The key scaleup parameter to determine photolysis reactor requirements is the total HO load to the desorber. For this estimate, an average HO concentration in the soil feedstock equivalent to 50 ppb 2,3,7,8-TCDD, 100 ppm 2,4-D, and 100 ppm 2,4,5-T was used. The scrubber solvent purge rate is based on maintaining a concentration in the recirculating solvent of total chlorophenols of 1 percent and corresponding 2,3,7,8-TCDD concentration of 2.5 ppm. This steady-state concentration is higher than that achieved during the limited duration pilot tests at JI. ITC has demonstrated in full-scale tests for a similar process that solvent containing greater than 30 ppm 2,3,7,8-TCDD can be successfully photolyzed (Reference 17). Also, bench-scale tests described in Section II.B.2 demonstrated successful photolysis of simulated scrubber solvent containing 0.1 percent of chlorophenol.

The key scaleup parameters in sizing the UV photolysis reactor are the reaction rate constant and the UV power requirement (lamp wattage). The rate constants for 2,3,7,8-TCDD determined from the JI and NCBC tests supported by laboratory kinetic data were used to establish reactor residence time. The primary scaling factor was the light energy

(wattage times exposure time) per unit of solvent; a value of 4 kWh/gallon, used for the pilot-scale system, was used for the full-scale reactor systems.

2. Soil Preparation

Soil can be processed by a large-diameter rotary desorber with minimal preparation because particle size and moisture are not critical to treatment performance and mechanical limitations. The pilot-scale unit was restricted to 1/2-inch soil particles because of mechanical clearance in the screw feeder. Air drying was required to enable the soil to be crushed and provide reasonable flow characteristics in the particular feed hopper and screw feeder. Proper design and layout of the soil feed hopper and selection of solid feed and transfer systems that can tolerate a wide variety of soil characteristics will enable moist soil types to be processed with only a coarse screening step to remove rocks or aggregates greater than about 1 to 2 inches. A rudimentary size reduction step, such as crushing, would be necessary for the oversized material to reduce it to this size.

For developing cost data for the full-scale system applied to JI, the soil preparation system includes a coarse screener/classifier, a jaw crusher to process all oversized soil to less than 1 inch, a feed hopper capable of holding 2 hours (approximately 20 tons) of feed, an enclosure to cover crushed soil and the soil preparation equipment, and a variable speed screw conveyor to transfer feed from the hopper to the desorber. Inventories (approximately 1.7 days or 400 tons) of prepared feedstock would be piled in soil storage bins. These bins are open on one side for a dump truck to unload. Wood beams frame the three other sides (40 feet wide by 10 feet deep by 7 feet high), with a seal-welded steel liner plate attached to provide a surface that can later be decontaminated. A tarp frame cover is located above each storage bin to provide protection from the weather (e.g., wind and rain), yet is high enough to allow the dump trucks to unload. The floor of each storage bin is covered to prevent contamination of the soil beneath and is bermed to prevent water draining

either into or out of the storage area. The same bin configuration is assumed for the seven quarantine storage bins for the treated soil. Material would be transferred between the piles and the preparation unit by a front-end loader. Adequate dust control measures (e.g., water spraying, covers) have been included.

3. Residuals and Wastewater Treatment and Disposal

Because the TD/UV photolysis process does not totally destroy the HO contaminants and a wastewater effluent is generated as a result of soil moisture collected and separated from the solvent, the full-scale system includes equipment for minimizing hazardous residues and treating aqueous effluents to enable discharge onsite or to the ocean. The hazardous waste residues can then be shipped to a disposal facility permitted under RCRA for the characterized hazardous constituents; or, if a permitted facility is not available at the time, it can be permitted to temporarily store the hazardous waste onsite, such as in Bunker 788. One or more bunkers may be additionally needed. As discussed in Section V.B.3, treatment processes for aqueous condensate and photolyzed scrubber solvent were not demonstrated as part of the JI pilot-scale testing. However, conventional unit operations have been identified, and design and performance criteria have been selected based on similar applications. Costs have been developed, using relatively conservative scaleup criteria.

High-efficiency filtration and activated carbon adsorption will be used to remove HO constituents from the aqueous condensate separated from the scrubber solvent. The system will be sized, based on treating the moisture derived from 10 tons per hour of feed soil containing 10 percent moisture, which represents about 5200 gallons per day of condensate. The condensate is assumed to contain 1000 mg/L total organic, 100 mg/L phenolic compounds, and 1 µg/L 2,3,7,8-TCDD. The concentration of soil particulates in the aqueous condensate was assumed to be 100 mg/L or 0.001 percent of the soil feed. An organic capacity loading of 0.1 gram organic/gram carbon and a total adsorbable carbon concentration of 300 mg/L (100 mg/L phenolics plus 20 percent of other organics) were used to

calculate carbon consumption. Spent carbon will be processed as feedstock in the thermal desorber to remove adsorbed organics to thus avoid generation of a waste residue. Successful carbon decontamination would need to be demonstrated by laboratory desorption tests similar to those used to develop soil treatability data discussed in Section II.B.1.

Photolyzed solvent will be processed to separate phenolic tar reaction products in a batch distillation system. Solvent vapors would be condensed and recycled to the scrubber system. The distillation "bottoms" would consist of the tars, trace levels of residual unconverted PCDD/PCDF and chlorophenols, and trace soil particulates not removed in the scrubber solvent filtration step before photolysis. The distillation system is sized to treat the entire scrubber solvent purge rate at an operating (bottoms) temperature up to about 482 °F, which is above the boiling point of Soltrol[®] 170. Tar generation is estimated to be 1 pound per ton of soil processed, assuming that the nominal design case of feed soil contains an average of 200 ppm combined 2,4-D and 2,4,5-T. Tar will be cooled and collected in steel drums for ultimate disposal as a hazardous waste (F027). Based on 20,000 tons of soil to be treated, approximately 20,000 pounds of tar (approximately 50 drums) would be generated. The tar is projected to contain a concentration of 2,3,7,8-TCDD of about 40 ppb; this results from concentration of the 1 ppb residual content of the photolyzed solvent in the distillation step. This concentration could be reduced by more extensive photolysis (higher reaction conversions), although this would require a larger photolysis system and higher operating costs (e.g., electrical power). Alternatively, residual PCDD/PCDF could be eliminated by one of several proprietary dehalogenation reagents currently under development for treating polyhalogenated aromatics in organic fluids such as mineral oil.

C. COST-ESTIMATING APPROACH AND BASIS

Estimating emphasis was placed on identifying the total project remedial scope. Because the remedial action would occur on a federal reservation, certain project tasks such as permitting and delisting with

EPA would be carried out by USAF or its agent. By considering the JI site-specific case for the cost estimate, existing conditions at the site eliminate the need for some workscope items, which might not be the case at some other contaminated site. Part of this approach is due to the conditions provided as a storage area. These items have been listed in the assumptions for the cost estimate (Section VI.C.1).

Data sources for all remediation activities other than actual treatment in the TD/UV photolysis process were primarily from cost experience derived from the excavation of TCDD-contaminated soil at similar sites, with supplemental information derived from Mean's Building Construction Cost Data (Reference 37, suitably adjusted for worker productivity and other allowances as per Table 7). Caution was used in directly applying vendor quotes and literature costs. Ocean shipping costs and associated dock-side charges were obtained by quotation.

A trial burn is included as part of the restoration project workscope. Preceding the treatment of soil on a production basis, the activity is assumed be performed within 4 weeks after system checkout testing. All sampling would be performed by a third party. Analysis would be performed at a field laboratory at the site, except for gas analysis (MM5 and VOST), which would be sent to a laboratory on the mainland. Ten weeks is allowed for data evaluation, document preparation, submission to EPA Region IX for review, and authorization to start full-scale treatment of JI soil. During this period, the equipment would be shut down, with only a small standby crew for security and preventive maintenance of the equipment. These costs are summarized in Section VI.D.2.

Feasibility study cost estimates are prepared to guide a project's evaluation of alternatives and planning, from information available at the time of the estimate. The final cost will depend on actual labor and material costs, final project scope, schedule, and other variables. As a result, the final project costs and bid prices are likely to vary from the

estimates presented herein. Because of these factors, funding requirements should be carefully reviewed before using any cost estimate to establish final budgets.

1. Assumptions

A cost estimate depends on the assumptions and criteria used to describe the cost estimate scope. As data accumulate and project parameters are refined, the assumption and resulting estimate should be reevaluated.

General and site-specific assumptions have been made in preparing this cost estimate:

- o For this cost estimate, the quantity of contaminated soil to be removed from the site for treatment is assumed to be 20,000 tons. Based on local soil density ("JI as received" per Volume III of Reference 1), the volumetric quantity is 17,200 yd³.
- o Adjustments have been made in each cost category for engineering design, services during construction, contingencies, and contractor overhead.
- o Initial TD/UV photolysis capital equipment cost was assumed at \$5,500,000. Capital amortization was computed based on a 5-year straight-line depreciation for study comparison with other technologies being considered by AFESC. A 7- or 10-year life may be more realistic in some cases and can vary from company to company. However, the shorter life basis will tend to show higher costs for equipment expense. A 90 percent utilization factor was also assumed in calculating the monthly use charge.

- o A lump sum of 8 percent of the total project cost is assumed for insurance and bonding charges. This item has been included in the general administration and overhead factor, which is standardized at 13 percent.
- o The final cost includes a fee of 8 percent for contractor profit based on an assumed cost plus fixed fee type of contract.
- o Personnel exposed to TCDD-contaminated soil would wear Level-C personnel protective gear, including air-purifying respirators, Tyvek[®] suits, nitrile gloves, and boot covers. Viton[®] gloves would be used with the solvent. Individuals working around the soil, but not directly exposed to it, would wear Level D gear. For Level D, safety shoes, coveralls, and work gloves are worn, with air-purifying respirators readily available. The use of Levels C and D personnel protective gear reduces worker efficiency, shortens work periods, and includes other health and safety requirements. For Level C, these effects increase labor requirements by at least two times over standard conditions. All onsite activities require site safety officers. A decontamination trailer and a truck wash station must also be available. All workers are assumed to have entry/exit physicals, undergo a 1-week health and safety training course, and have weekly safety meetings while onsite. For contractor permanent personnel, these requirements may be satisfied by company physicals and training performed on a normal periodic basis during the year.
- o Dust control would be provided by water spray where closed systems are not incorporated.

- o Onsite security is necessary during all construction, excavation, and treatment activities. An additional cost for security was not included in this estimate, since the site is located within an existing security system.
- o Site area requires no special preparation or clearing for excavation. Existing storage area conditions are satisfactory for truck hauling without extra treatment.
- o All personnel necessary to support the remedial action are assumed to originate from the mainland. Use of Holmes and Narver (H&N) personnel at JI is considered for minor activities at most. For travel costs, Tulsa, Oklahoma, was used as the initial point for round-trip air fare. Housing at JI is assumed to be available. Per diem is at the JI rate of \$19 per day. Personnel supporting the site buildup and trial burn are assumed to return home during the standby period. Personnel supporting the subsequent soil restoration activity are assumed to remain on the island until the work is completed and equipment is disassembled, decontaminated, and packaged for return shipment. No cost provision is included in the estimate for personnel "rest and recreation" trips to Honolulu or the mainland because each segment is less than 6 months.
- o Equipment to perform excavation (front-end loaders), hauling (dump trucks), grading (crawler tractor with blade), and lifting (forklifts) exceeds availability at JI and must be transported to the island. Equipment from the Oakland area is assumed because of expected greater availability than Honolulu.
- o Because another long-term cleanup project (Johnston Atoll Chemical Agent Disposal) is expected at JI when the dioxin-contaminated soil remedial action would likely occur,

present excess electrical and water supply capacity is assumed to be already allocated. Therefore, electrical power generating equipment (1200 kW) is assumed to be transported from the mainland for use. Process design changes are assumed to reduce the freshwater needs by 93 percent of the normal use by the process. The remaining 4000 gpd can be supplied from the island system within the stated constraint. Allowances are provided for construction to tie in the lighting with the island system and provide seawater supply and treated effluent outflow to the ocean.

- o The TD/UV photolysis system undergoes the following changes before being shipped from the mainland. The burners are changed from natural gas to diesel oil to accommodate use of a common fuel at JI. Also, the cooling system is modified to allow use of seawater to substantially reduce fresh water needs. A cooling tower as planned for the NCBC remedial action would not be as efficient in the high temperature, high humidity conditions expected at JI.
- o Liquid nitrogen is not available in Hawaii. Nitrogen is assumed to be produced in sufficient quantity and quality by a small portable nitrogen production plant, which is electrically operated. Initial capital equipment cost was assumed to be \$180,000. Monthly use charge was determined by the same method discussed for the TD/UV photolysis equipment.
- o Diesel fuel storage at the site will be necessary to operate the electric generators, desorber, nitrogen production plant, water treatment plant, and vehicles. A 12,000-gallon tank is assumed for this purpose. Fuel is assumed to be obtained from the island's supply tank. Because the JI fuel truck has limited capacity compared to the expected site

fuel demand, a fuel truck must also be brought to the island to transport the fuel between the two storage tanks.

- o Well-maintained trucks and containers would be emphasized. All truck windows would be kept closed while in the excavation zone, allowing the use of Level D protection.
- o Hauling of contaminated soil will be made by equipment that remains within the contaminated area of the site; therefore, decontamination of equipment need only occur at the end of the project. Similarly, treated soil that is declared clean will be hauled to previously excavated areas, following routes outside the defined contamination zone. This approach precludes contaminated "clean" trucks, but will necessitate preplanning the grid plot excavation order and changing the visual boundary between clean and contaminated areas.
- o The treatment process area is placed within a clean area but next to a contaminated area where excavated soil can be stockpiled and fed into an input chute of the soil treatment facility without requiring decontamination of equipment.
- o The storage area is assumed to be sufficiently strong so that concrete floor slabs or footings are not needed to support equipment. Any supports for leveling equipment are considered to be included in the cost of equipment setup.
- o It is assumed that the TD/UV photolysis process will already have an RCRA dioxin/furan permit so that the required permit for the JI soil remedial activities is a site-use permit of the technology.

- o A small allowance is assumed for contractor input preparation for the site Part B permit and attendance for personnel needed at the permit hearing conducted by Region IX in Honolulu. Other costs for Part B permitting and delisting with EPA are considered as separate costs by the USAF, or its agent. Where new technologies are involved, more contractor involvement should be seriously considered.
- o It is assumed that the delisting requirements would be specified by EPA Headquarters before a trial burn, which would be performed after the TD/UV photolysis process is set up at the site and readied for operation. Samples would be collected for analysis in accordance with permit and delisting requirements. It is further assumed that the results are such that the treated soil can meet permit and delisting requirements. Subsequent treated soil monitoring for specified compounds is then considered as an in-process quality assurance (QA) procedure to release the excavated bottoms and temporarily stored treated soil for hauling to these declared clean excavated areas. Any excavation bottoms not meeting QA requirements must be further excavated. Any treated soil not meeting QA requirements is returned to feedstock for reprocessing.
- o Sampling and analytical activities would be performed by qualified personnel following protocols accepted by EPA and the USAF or its agent. During the trial burn, it is assumed that a third party would perform all necessary sampling. But during the production processing, it is assumed that operating personnel would take soil, air, and water monitoring samples as may be prescribed. The protocols would include appropriate QA to support the activities so that any third-party involvement is limited to an audit function, as necessary.

- o Treatment of the contaminated soil by the TD/UV photolysis process would be the rate-limiting step for the site remedy. Other equipment is sized larger to avoid process bottlenecks, and adequate storage is provided to avoid weather or excavation delays.
- o After treatment, the original soil will be returned to the excavation site. It is expected that up to 10 percent of the original soil volume will be lost during treatment. Clean dredged coral from island stockpiles, as available, will be used to cover the replaced soil so that the site may be recontoured for its final intended use.
- o A cost estimate depends on the assumed schedule. Based on the pilot-scale testing, the permitting process with EPA Region IX appears to be the major uncertainty, and may take 12 to 24 months. Weather does not appear to be a constraint. Facility construction is assumed to be minor. The assumed schedule of the site remedy is shown in Table 38. Cost adjustments (particularly in equipment use charges) would be necessary if the assumed schedule is significantly delayed.
- o TD/UV photolysis soil treatment requirements for use of soils as feedstock are a moisture less than 20 percent and a 1-inch size. The thermal desorber will handle feedstock having higher moisture content or larger size at some sacrifice in capacity.
- o It is assured that an RCRA-permitted disposal facility will exist at the completion of the remedial activity so that all hazardous wastes that cannot be recycled as feedstock into the TD/UV photolysis process can be shipped to the mainland for disposal. If this condition does not exist, a permit

TABLE 38. ASSUMED SCHEDULE FOR SITE RESTORATION

Schedule Element ^a	Duration (weeks)
Preparatory Work Period by Contractor	
Detailed design, procurement, and equipment fabrication/ troubleshooting for first field use. (See footnote b for likely critical path because of permitting with Region IX.)	52
Equipment Use Period	
Transport from Tulsa, Oklahoma, and unloading at site ^c	6
Equipment erection	1.5 ^d
Equipment testing, debugging, and checkout test	2 ^d
Trial burn ^e	4
Standby awaiting permission to proceed from Region IX ^f	10
Treatment of 20,000 tons of soil	14
Decontamination and disassembly of equipment	2.5
Load and transport of equipment to Tulsa, Oklahoma ^c	6
Refurbishment of equipment	3
Total Equipment Use Period	50

a. Schedule applies following contract award; however, there may be need for allowed time because of permitting uncertainty (see footnote b).

b. In parallel with this effort are the activities of permitting and site preparation by the USAF or its agent. The permitting for the JI remedial work is with EPA Region IX. The pilot-scale testing suggests that the duration for the permitting process will take longer than is shown for contractor activities. The schedule should have provision for 12-24 months for permitting from initial submittal of the request to receipt of an approved permit.

c. Use overland transportation to Oakland, California; then ship to Honolulu, Hawaii; and barge to JI. Use same means on the return to Tulsa.

TABLE 38. ASSUMED SCHEDULE FOR SITE RESTORATION (CONCLUDED)

d. Based on ITC input, pretreatment and TD/UV photolysis modules would be initially assembled and debugged after construction at Tulsa and this was estimated at 3.5 weeks; subsequent projects were expected to require less time as crews become fully trained. Experience from other projects using similar large-scale equipment indicates these estimates are probably low.

e. It is assumed that a trial burn will be required by Region IX before giving permission to proceed with production treatment.

f. The standby period allows for completion of sample analysis, evaluation of data, preparation of the trial burn report, submission of the report to Region IX for review, resolution to any comments, and Region XI authorization to proceed with the full-scale restoration project.

for interim storage of hazardous wastes onsite (e.g., Bunker 788 and others as necessary) will be required, which is not included as a cost.

2. Cost Categories

a. Cost Category 1, Common Remedial Costs

This category includes the costs for all common site preparation and removal work required to support the TD/UV photolysis (or any other) soil treatment process. Also included are all utility connections to existing JI systems (lights, telephone, freshwater) exclusive of the area inside the treatment process area. Because there is expected to be insufficient electrical power capabilities to support the project, three 400 kW diesel-powered electrical generators would be brought to JI to anticipate for these needs. A 12,000-gallon storage tank for diesel fuel and an 8000-gallon fuel truck would be brought in.

Ancillary facilities are needed for any treatment process and would be located outside the treatment process area. These include office and breakroom trailers, decontamination facilities, and a 50-gpm

water treatment facility consisting of a four-stage process train of sand filtration, 5-micron cartridge filters, activated carbon, and 5-micron post filters.

The decontamination station would consist of a below-grade rectangular sump covered with heavy grating and surrounded by splash walls and a roof or some similar pool type of structure. The station would be supplied with water, power, and phone connections and would pump the spent washwater into a pressurized sewer connecting to the water treatment facility. This station would be used to decontaminate trucks and equipment, as needed.

Eighteen personnel, including one for safety, are estimated to assemble the common support facilities at the site. This work consists of building four contaminated soil storage bins and seven quarantined treated soil storage bins; setting up the electrical generation equipment and routing the associated wiring; setting up the water treatment facility, office, employee, and laboratory trailers; and routing all the utility piping and wiring. After this work is completed, nine of these personnel would return to Tulsa. Nine personnel remain to support the Category 1 (4) and Category 2 (2) activities during the trial burn, and another three construction personnel are expected to remain to complete the storage bins. Personnel depart after the trial burn with a complement of 13 personnel to return to perform Category 1 activities when the full-scale soil restoration is to start.

The 20,000 tons of contaminated soil would be excavated by a crew of three, operating one 4 yd³ front-end loader and two 10 yd³ dump trucks. Twenty-four loads per day, with a maximum soil quantity of 240 tons, would be loaded over a 6-hour period at the excavation area and dumped at the contaminated soil storage bins. Another front-end loader (2 yd³) is operated to transfer soil from the storage bins to the soil preparation plant and the soil treatment plant feed hopper. A water truck is expected to be operated during the excavation activities to reduce

spread of contamination. A crew of three would operate equipment in the clean zone. A rolloff truck would be used to move 15 ton enclosed steel boxes, which collect the treated soil, to the quarantine soil storage bins. Upon release of a treated soil stockpile, a front-end loader and dump truck are used to haul the clean soil to clean excavation sites. The excavation crew would also map excavation progress, lay out road routes, and change the boundary between contaminated and clean areas as needed.

As mentioned, the average rate of excavation would correspond to the average daily throughput at the soil treatment facility. A soil volume equivalent to about 1.7 days, 400 tons of operation at the JJ site treatment facility would be held on reserve at the site for periods of inclement weather or other delays in excavation. The excavation equipment can operate at a maximum rate twice the TD/UV photolysis process soil treatment rate, and the crew can work overtime during daylight hours, to enable the soil inventory to catch up after a period of depletion.

The contaminated area would be divided into workable zones separated by haul routes. The zones would be sequentially excavated in layers (6 to 12 inches), and then refilled with the treated soil, once the soil analyses for a particular zone pass QA requirements.

Once the site has been cleaned of contaminated soil, final restoration would consist of grading the treated soil with a blade-afixed crawler tractor and then covering this area with clean coral stockpiled elsewhere on the island. Approximately 10 percent of the original soil mass is expected to be lost in processing because of volatilization of moisture; moisture content of the excavated soil is assumed to be 10 percent for the reference case. The steel rolloff boxes used for daily operations would be decontaminated and salvaged.

Included in this category are the transportation costs to bring equipment from the mainland, assumed to be at or near Oakland, California. A list of the major units with their volumes and weights is

presented in Table 39. Construction and crew personnel are listed in Table 40 according to project phases.

b. Cost Category 2, Common Operating and Monitoring Costs

During operation of the TD/UV photolysis process (or any other treatment process), substantial monitoring and ancillary site costs are necessary to certify the treatment efficiency and to ensure permit compliance, and obtain soil delisting data. An onsite coordinator has been included in the cost estimate to act as a representative for necessary day-to-day decisions and to oversee the common support activities.

An independent group of five sampling technicians would be brought in to perform all sampling necessary during the trial burn to support the data submittal to Region IX according to requirements in the permit. Sampling would include feedstock and treated soil, solvent, process waste streams including filter material, gas emissions (MM5 and VOST), and ambient air. The sampling plan and protocols would be prepared for Region IX review and approval as part of the permit application. Because of the special equipment required, all MM5 and VOST samples would be packaged in accordance with Department of Transportation regulations and flown to the contracted analytical laboratory in a timely manner to meet protocol time requirements. All other samples are planned to be analyzed concurrently at the mobile onsite laboratory. The onsite laboratory would be set up and equipped with a HRGX/LRMS, a HRGC, and ancillary equipment for the trial burn and be left to support the full-scale restoration activity later. For the trial burn, two chemists are planned to operate the laboratory for dioxin/furan, HO, organic, and inorganic analyses.

A sampling plan for the full-scale restoration would be prepared to guide the site excavation. Given the cleanup level, desired statistical accuracy, confidence limits, and detection levels, the necessary sample spacing, compositing, and QA/QC protocol should be developed. At this time, it is assumed that one composite sample would be analyzed for every 15 tons of treated soil. Also, a composite sample would

TABLE 39. ASSUMED MAJOR EQUIPMENT AND FACILITIES BEING TRANSPORTED TO JI

Cost Category	Item	Quantity	Estimated Volume (1000 ft ³)		Estimated Weight (1000 lb)	
			Unit	Total	Unit	Total
1 and 2	Front-end loaders (4 CY)	2	1	2	41	82
	Front-end loader (2 CY)	1	1	1	19	19
	Dump truck (10 CY)	3	2	6	16	48
	Crawler tractor with blade	1	1	1	22	22
	Fork lifts	2	1.5	3	17	34
	Water truck (5,000 gal)	1	4	4	38	38
	Fuel truck (8,000 gal)	1	4	4	38	38
	Fuel storage tank (12,000 gal)	1	2	2	16	16
	Rolloff truck carrying 5 rolloff boxes	1	4	4	25	25
	Trailer carrying three 400 kW diesel power generators	1	4	4	30	30
	Trailer carrying water treatment facility	1	4	4	35	35
	Trailer with miscellaneous equipment	1	4	4	19	19
	Trailer with storage bin material ^a	1	4	4	25	25
	Office trailers ^b	2	5	10	6	12
	Decontamination trailers	2	5	10	12	24
	Monitoring laboratory trailer	<u>1</u>	5	<u>5</u>	60	<u>60</u>
	Categories 1 and 2 subtotals	22		68		527

TABLE 39. ASSUMED MAJOR EQUIPMENT AND FACILITIES BEING TRANSPORTED TO JI
(CONCLUDED)

Cost Category	Item	Quantity	Estimated Volume (1000 ft ³)		Estimated Weight (1000 lb)	
			Unit	Total	Unit	Total
3 and 4	Trailer with module	1	12	12	120	120
	Trailers with modules	8	3.8	30	30	240
	Trailers with miscellaneous equipment	2	4	8	19	38
	Nitrogen plant	<u>1</u>	2	<u>2</u>	15	<u>15</u>
	Categories 3 and 4 subtotals	<u>12</u>		<u>52</u>		<u>413</u>
Total for all categories		34		120		940

a. Bin material is assumed left at JI for salvage use.

b. One of the office trailers is used for a worker break room.

TABLE 40. ASSUMED PERSONNEL BEING FLOWN TO JI

<u>Category</u>	<u>Function</u>	<u>Quantity</u>		
		<u>Initial Setup</u>	<u>Trial Burn</u>	<u>Full-Scale Restoration</u>
1	Construction/assembly	17 ^a	3 ^b	--
	Excavation crew			
	Foreman	--	1	1
	Front-end loader operators	--	1	2 ^c
	Dump truck operators	--	1	2 ^c
	Restoration crew			
	Rolloff truck operator	--	--	1
	Front end loader operator	--	--	1
	Dump truck operator	--	--	1
	Support crew			
	Water truck driver	--	--	1
	Fuel truck driver	--	--	1
	Fork lift operator	--	--	2
	Health and Safety technician	1	1	2
2	On-scene coordinator	1	1	1
	Monitoring lab			
	Chemists	--	2	5 ^d
	Lab technicians	--	--	4 ^d
	Trial burn sampling technicians ^e	--	5	--
	Utilities operators ^f	--	2	6
Categories 1 and 2 subtotals		19	17 ^g	29 ^h
3 and 4	Site superintendent	1	1	1
	Clerk	1	1	1
	Engineer/safety personnel	1	1	2
	Maintenance personnel	2	1	2

TABLE 40. ASSUMED PERSONNEL BEING FLOWN TO JI (CONTINUED)

Category	Function	Quantity		
		Initial Setup	Trial Burn	Full-Scale Restoration
Operating Crew ⁱ				
	Supervisor	1	1	4
	TD/UV operators	2	2	8 ^j
	Yard operators	1	1	4
	Soil feed operator	1	1	4 ^j
	Relief operators	<u>1</u>	<u>1</u>	<u>4</u>
Categories 3 and 4 subtotals		<u>11</u>	<u>10^g</u>	<u>30^h</u>
Total for all categories		30	27	59

a. Eight personnel return to Tulsa after assembly/buildup completed. Three of the remaining change roles to do excavation crew work during the trial burn; another two change roles to be utility operators during the trial burn (Category 2).

b. Construction personnel remaining to complete the building of the 11 soil storage bins.

c. Also perform field sampling during the full-scale restoration after qualifying training to approved protocols.

d. During full-scale restoration, the lab is expanded to four shifts. A fifth chemist acts as supervisor, coordinating activities and performing QA/QC function.

e. Perform independent sampling for the trial burn only, consist of 2 soil/process sample technicians and 3 gas sample train (MM5 and VOST) technicians.

f. Support diesel electric generators and water treatment facility.

g. Two each Category 1/2 and Category 3/4 personnel remain during standby period following the trial burn. Act as watchmen, operate any support equipment as necessary, and perform preventive maintenance. Midway through the standby, they are replaced by another four personnel who will remain through the full-scale restoration activity.

h. After the full-scale restoration activity is completed, 16 Category 1/2 and 19 Category 3/4 personnel return to Tulsa. This leaves 12 Category 1/2 and 11 Category 3/4 personnel to disassemble, decontaminate, and load equipment for site closure.

TABLE 40. ASSUMED PERSONNEL BEING FLOWN TO JI (CONCLUDED)

i. During full-scale restoration, the TD/UV photolysis process is expanded to four shift crews for continuous operation.

j. Also perform sampling at their positions during the full-scale restoration after qualifying training to approved protocols.

be taken from soil at the bottom of each 20 by 20 foot excavation to ensure untouched soil has constituent concentrations that are less than criteria set forth by EPA for declaring the site nonhazardous. A 1 ppb 2,3,7,8-TCDD cleanup target has been assumed for this estimate, consistent with the land fill disposal criteria discussed in Section V.B.1.d (see also Reference 13).

The monitoring program during the full-scale restoration activity would also include sampling and analysis of site ambient air and waste streams exiting the TD/UV photolysis process. A network of four perimeter high-volume air samplers would be installed to collect background data and monitor offsite emissions during excavation, operation of the soil pretreatment facility, and operation of the TD/UV photolysis process. At the TD/UV photolysis process and soil pretreatment facilities, monitoring of the waste streams from the process would occur at various compliance points. Routine monitoring should include the treated soil, treated solvent residue, and treated aqueous condensate wastewater. Periodic monitoring of the desorber vent would be required to demonstrate that the emission controls were operating properly. The very small volume of vent emissions plus the use of carbon adsorption filters preclude the need for routine and/or continuous monitoring of HO compounds.

The mobile onsite laboratory would be operated during the full-scale restoration activity on a four-shift continuous basis to minimize analytical costs and improve sample turnaround time to 48 hours or less. Each shift crew would consist of a chemist and laboratory

technician. Another chemist would supervise the laboratory operations, perform necessary equipment maintenance, and conduct the QA/QC program.

Additional common operating costs will include user diesel oil (electrical power generation). The diesel fuel was assumed to have a thermal value of 124,000 Btu/gal. Electrical conversion was assumed at 30 percent or 10.90 kWh/gal. Operation at 100 kW would utilize 220 gallons of diesel fuel per day. This cost category also includes the operation of the 50-gpm water treatment facility. Sources of wastewater that may be contaminated include accumulated excavation site runoff, personnel and equipment decontamination facilities, soil storage runoff, and miscellaneous washdown sources. It is assumed that waste water (condensate) from the scrubber solvent would be recycled with soil feed stock for treatment. Seawater used for cooling the scrubber could be returned to the sea without treatment.

Included in this category are the transportation costs to bring listed equipment from the mainland (Table 39). The crew personnel of this category are listed in Table 40.

c. Cost Category 3, TD/UV Photolysis Process Setup/Removal Costs

ITC would be responsible for the mobilization and demobilization of the soil pretreatment facility and the TD/UV photolysis process within the treatment process area. These units would be constructed in prefabricated (prewired, prepiped) trailer-mounted or skid-mounted modules that could be transported by truck, although several would require special permits. They would be preassembled and tested at ITC's facilities in Tulsa, Oklahoma. The modules plus support equipment would be shipped in 12 trailer modules (see Table 39) to JI, where they would be erected and retested before the trial burn. TD/UV photolysis process labor costs for the trial burn and standby period are included in this cost category. After onsite operation (Category 4), the units would be decontaminated, disassembled, and shipped back to ITC's facilities for refurbishment (postoperation maintenance and repairs).

An area of about 100 by 200 feet will contain all the soil pretreatment, feedstock storage, desorber, scrubber, UV photolysis reactor, emission controls, nitrogen production, and process wastewater treatment and storage. Maximum elevation of the assembled process systems is less than 20 feet.

Twelve of the full crew discussed in Category 4 would be onsite during the equipment assembly and shakedown. Eleven of this crew (see Table 40) would remain onsite during the trial burn that precedes the production soil treatment operation. Two personnel would remain during the standby period between the trial burn and the full-scale restoration activity. Eleven of the crew remain after the full-scale restoration activity to perform disassembly, decontamination, and loading of the equipment. Travel costs for the full crew are shown in Category 4.

d. Cost Category 4, TD/UV Photolysis Process Operation and Maintenance Cost

During operation of the soil pretreatment and TD/UV photolysis facilities, ITC would be responsible for all operating and maintenance costs within the treatment process area, including labor, utilities, materials, equipment use charges, waste disposal, and other operating costs.

An onsite operating crew of 30 would be provided to enable around-the-clock operation. The crew would include one site superintendent, four shift supervisors, one clerk, two maintenance personnel, eight TD/UV photolysis process operators, four yard operators, four soil pretreatment operators, four relief operators, and two engineer/safety personnel. Most of the personnel would be grouped into four rotating shift crews to maintain three 8-hour shifts per day. Offsite personnel would include a project manager, buyer, and secretary; this labor would be part-time.

Labor costs are computed at the rate of 2.16 times the base salary (GA and fee not included). The full operations crew would be onsite for 14 weeks of full-rate operation to treat 20,000 tons of soil.

The major utility and fuel requirements necessary for the operation of the TD/UV photolysis process include diesel fuel, nitrogen, electrical power, and water. Consumption rates are based on 10 tons/hour (10 percent average moisture) of desorber throughput. The diesel fuel supply planned to operate the desorber and nitrogen production plant is the same as that used to operate the electrical power generators described in Cost Category 1. At a thermal use of 2.4 million Btu/ton of soil treated, which is 10 tons/hour, the daily use rate is about 4800 gal/day. Nitrogen use in the desorber (as makeup) is about 600 ft³ per ton of soil treated or 100 scfm at a time-based rate. The nitrogen production plant produces this rate at 162 ft³/kW-h. The electrical power demand to operate the facility is 610 kWh/hour for the photolysis operation, 37 kWh/hour for the nitrogen production plant, and 225 kWh/hour for operation of other electrical equipment, totaling 872 kWh/hour for Category 4. This represents a diesel fuel consumption of about 1920 gal/day. Including the 220 gal/day of diesel fuel consumed in Category 1 with these two identified in Category 4, the site daily consumption would be about 7,000 gallons, which would require the 12,000 gallon fuel storage tank to be refilled from the JI supply daily. At a 10 tons/hour soil treatment rate, the site electrical power demand is 972 kW (includes 100 kW from Category 1), which is met by operation of the three 400 kW diesel fueled generators.

Material costs include initial fill and replacement of Soltrol[®] scrubber solvent and isopropyl alcohol used during photolysis and during periodic cleaning of the UV photolysis reactor. Activated carbon used for controlling organic vent emissions and treating aqueous condensate is included as a material cost.

An allowance of 1 percent of the initial capital equipment cost has been included for general maintenance materials used onsite. Labor costs for routine maintenance personnel are included in the operating crew. Other maintenance expenses consist of replacement costs for filter media and cleaning solvents. In addition to maintenance, other operating costs include health and safety materials and miscellaneous supplies. Costs (equivalent to 1 percent of the initial capital equipment cost) to refurbish the equipment after returning to ITC's facilities are included in Category 3.

Based on the assumption stated earlier, the capital equipment monthly use charge was calculated to be \$102,000. From the schedule in Table 38, the projected use of the equipment is over a 12-month period, although the actual treatment of 20,000 tons of soil occurs during only 3.3 months. The remaining 8.7 months are consumed by equipment shipping, setup, trial burn, standby during the trial burn data review, decontamination, disassembly, and refurbishment.

Disposal costs were calculated by considering the estimated waste quantities generated from the TD/UV photolysis process operation. Waste included tars from the solvent treatment system, filter media, and used health and safety gear (e.g., protective clothing). Spent carbon from emission control and wastewater treatment were not included as waste requiring disposal; this material will be treated with contaminated soil in the TD/UV photolysis process.

Included in this category are the transportation costs for the TD/UV photolysis process operations crew, which is listed in Table 40.

D. COST ESTIMATE

1. Reference Case

The estimate for the reference case is summarized in Table 41. A detailed breakdown is presented in Appendix W, Exhibit 1. The analysis

TABLE 41. SUMMARY OF SITE REMEDIAL COSTS FOR TD/UV PHOTOLYSIS TREATMENT OF 20,000 TONS OF SOIL AT JI SITE

	<u>Cost^a</u> <u>(\$1000)</u>	<u>Cost</u> <u>Per Ton^b</u> <u>(\$)</u>	<u>Cost Per</u> <u>Cu Yd^c</u> <u>(\$)</u>	<u>Percent</u>
Category 1: Common Remedial Costs				
Mobilization	255	12.8	14.8	2.2
Facilities and utilities	1,273	63.6	74.0	11.0
Excavation/site restoration equipment and material	1,130	56.5	65.7	9.8
Shipping	791	39.6	46.0	6.9
Labor	738	36.9	42.9	6.4
	<u>4,187</u>	<u>209.4</u>	<u>243.4</u>	<u>36.3</u>
Category 2: Common Operating and Monitoring Costs				
Coordination	51	2.5	3.0	0.4
Monitoring and analysis	960	48.0	55.8	8.3
Facility operations	356	17.8	20.7	3.1
	<u>1,367</u>	<u>68.3</u>	<u>79.5</u>	<u>11.8</u>
Category 3: TD/UV Photolysis Process Setup Costs				
Planning and site preparation	165	8.3	9.6	1.4
Shipping	915	45.7	53.2	7.9
Labor	374	18.7	21.8	3.3
Material	114	5.7	6.6	1.0
	<u>1,568</u>	<u>78.4</u>	<u>91.2</u>	<u>13.6</u>
Category 4: TD/UV Photolysis Process Operating and Maintenance Costs				
Equipment use charge	1,845	92.3	107.3	16.0
Utilities and fuel	886	44.3	51.5	7.7
Maintenance and materials	637	31.8	37.0	5.5
Labor	893	44.7	51.9	7.7
Waste disposal	164	8.2	9.5	1.4
	<u>4,425</u>	<u>221.3</u>	<u>257.2</u>	<u>38.3</u>
TOTAL COST	<u>11,547</u>	<u>577.4</u>	<u>671.3</u>	<u>100.0</u>

a. These costs in 1986 dollars include engineering, insurance and bonding, administrative contingency, and contractor fee adjustments. Refer to Appendix W, Exhibit 1, for the applied cost burdens.

b. Cost per ton based on 20,000 tons.

c. Cost per cubic yard based on 17,200 yd³.

backup for the cost estimate is presented in Appendix X. This estimate encompasses a comprehensive scope of transportation, excavation, soil preparation, and TD/UV photolysis process treatment costs (direct and indirect costs) for 20,000 tons of soil. Estimated total cost is \$11.5 million, or approximately \$577/ton (\$671/yd³).

Category 4, TD/UV photolysis process operating and maintenance costs, represented the largest percentage of the project estimate at \$4.4 million or 38.3 percent. Next highest was Category 1, common remedial costs, at \$4.2 million or 36.3 percent.

Because of the remoteness of JI in the Pacific Ocean, the total equipment shipping costs represent about 18 percent of the project cost or \$1.7 million (Table 41). The TD/UV photolysis process equipment amounted to slightly more than half at \$0.9 million with common support equipment at \$0.8 million. The significance of the latter is due to the expected unavailability of electrical power supply at the island and need to bring all the equipment for the excavation and restoration field work. Holmes and Narver have very little equipment compared to the restoration project's needs.

Changes in the work scope, soil volume, site conditions, shipping arrangements, criteria, or contingencies would correspondingly affect the estimate costs. Without careful consideration of these fundamental cost determinants, these estimates should neither be inferred to be representative for any other site, nor should estimates prepared on a different basis by other parties be considered equivalent.

2. Trial Burn

The cost estimate for the restoration reference case conservatively assumes that a trial burn will be required to demonstrate that the full scale TD/UV photolysis process can meet permit requirements for treating the HO-contaminated coral. As discussed in Section VI.C, the

trial burn was assumed to span 4 weeks, followed by a 10-week standby period to prepare and cycle the data evaluation through Region IX and obtain authorization to start soil treatment. Extended schedule and additional work scope increase costs over those necessary to only treat 20,000 tons of coral. For example, the ITC technology may already have an RCRA Subpart B permit when the JI site-specific permit application is submitted. Assuming the available test data for the Subpart B permit was sufficient, Region IX could exclude need for any trial burn before the treatment of soil. Rather, a short confirmation test run at the planned operating conditions with in-process sampling and field analysis could be an alternate approach. If results met permit requirements, soil treatment would be allowed to start without further delay.

The detailed cost data for the reference case (Appendix W, Exhibit 1) were reviewed for possible cost savings if the alternate approach were to occur. Two weeks were assumed to complete confirmation test activities. The summarized estimate is presented in Table 42 and shows an estimated cost impact of about \$1.5 million or 13 percent of the reference case total. This is equivalent to \$75.0/ton (\$87.2/yd³). Equipment use charges are the dominating factor at \$983,000, largely due to the nonuse standby period following the trial burn. Labor costs total \$293,000. The additional scope, independent sampling (shown within the labor costs), and offsite gas sample analysis total \$185,000. When the total impact estimate is averaged over the 12-week period, the rate is \$120,000/week, which is approximately 1 percent of the reference case estimate. Therefore, significant savings can be achieved by shortening the evaluation period to obtain the Region IX permission to proceed with full-scale soil treatment.

E. SENSITIVITY ANALYSIS

A sensitivity analysis was conducted on six key variables (soil quantity, shipping, energy (diesel fuel), labor rates, TD/UV photolysis process equipment use charge, and HO concentration) to help assess the effect of specific assumptions on overall cost. Except for soil quantity,

TABLE 42. ESTIMATED COST IMPACT OF TRIAL BURN^a

<u>Category</u>	<u>Item</u>	<u>Cost (\$1000)</u>
1 and 2	Engineering support ^b	23
	Equipment use charges ^c	522
	Labor ^{d,e}	193
	Offsite chemical analysis ^e	<u>103</u>
	Subtotal	841
3 and 4	Equipment use charges ^c	461
	Labor ^d	110
	Diesel fuel ^f	<u>44</u>
	Subtotal	615
	TOTAL	1,456

a. Assumes 2-week confirm test in lieu of 4-week trial burn and 10-week standby period.

b. Assist in preparation and review of evaluation report to Region IX.

c. Equipment remains at JI during standby period.

d. Includes per diem and extra travel (18 trips).

e. Includes impact independent sampling and MMS/VOST sample analyses.

f. Assumed at 5 percent of reference case cost.

key variables were doubled, and then halved, to identify their effect on the overall remedial cost. Because the 20,000 tons represent an upper bound for the soil quantity, only a half value or 10,000 tons was included in the sensitivity analysis.

An additional variable, system capacity, was also evaluated because of the influence soil moisture and the required removal efficiency (final and

initial PCDD/PCDF concentrations) have on the process feed rates. Maximum and minimum feed rates chosen were 13 and 7 tons per hour, respectively, which represent ± 30 percent of the 10 tons per hour rate used in the reference case. Soil moisture can also affect fuel requirements.

Results of this analysis are shown in Table 43 and can be used to identify "best case" and "worst case" scenarios, and help adjust contingencies or reserve funds accordingly. The first variable, soil quantity, is the primary underlying assumption that, in turn, determines a large number of other assumptions and parameters. The other five variables (shipping, energy cost rates, labor, equipment use charge, HO concentration, and feed rate) are variants in consumption and/or unit costs, which have a lesser impact on remedial cost. Other lesser variables, and an imponderable number of combinations, could have a measurable impact on costs, but they are beyond the scope of this study.

1. Quantity

Soil quantity will likely be the most important variable because it directly impacts cost and schedule in nearly every cost category. Furthermore, preexcavation estimates of soil volumes are often inaccurate because of limited sampling in the field and uncertain criteria. Therefore, project planning and budgeting need to consider the accuracy of the soil volume estimate and the corresponding cost sensitivity. The reference site estimate assumes that 20,000 tons (17,200 yd³) are processed in a total of 14 weeks. In addition, there are substantial fixed time and cost requirements to set up and dismantle the TD/UV photolysis process and all ancillary equipment. Therefore, substantial economies of scale are associated with processing larger volumes of soil. As Table 43 indicates, a reduction to about 10,000 tons (8,600 yd³) increases the unit cost by \$360.0/ton (\$418.7/yd³, a 62 percent increase) to \$937.4/ton (\$1090.0/yd³). This quantity is close to the 9800 tons stated in Section I.B.3. Table 44 compares the four general cost categories for

TABLE 43. SUMMARY OF SENSITIVITY ANALYSIS

	Cost Categories \$/ton				Resultant Total Cost ^a	
	Common Remedial	Common O&M	TD/UV Site Setup	TD/UV Facility O&M	\$/ton	\$ (x 1000)
<u>Reference Case Costs</u>	209.4	68.3	78.4	221.3	577.4	11,547
<u>Quantity</u>						
Halve to 10,000 tons (8,600 yd ³)	+161.7	+36.6	+78.4	+83.3	937.4	9,374
<u>Shipping Cost</u>						
Double	+39.7	--	+45.9	--	663.0	13,259
Halve	-19.8	--	-23.0	--	534.6	10,691
<u>Fuel Costs (diesel)</u>						
Double	--	+2.8	--	+44.2	624.4	12,487
Halve	--	-1.4	--	-22.1	553.9	11,077
<u>Labor Cost</u>						
Double	+28.0	+26.1	+15.3	+36.8	683.6	13,672
Halve	-14.0	-13.1	-7.6	-18.4	524.3	10,486
^b						
<u>TD/UV Photolysis Equipment Use Charge</u>						
Double	--	--	--	+92.0	669.4	13,387
Halve	--	--	--	-46.0	531.4	10,627
<u>NO Concentration^c</u>						
Double	+8.0	--	+0.4	+33.7	619.5	12,390
Halve	-4.0	--	-0.2	-24.0	549.2	10,984
<u>System Capacity</u>						
1.2 Feed rate (13 T/hr)	-12.2	-8.8	--	-25.0	531.4	10,628
0.7 Feed rate (7 T/hr)	+18.2	+11.0	--	+27.0	633.6	12,672

TABLE 43. SUMMARY OF SENSITIVITY ANALYSIS (CONCLUDED)

- a. These costs, in 1986 dollars, include engineering, contingency, general administration, and contractor profit adjustments. Refer to Appendix W, Exhibit 1, for the applied burdens.
- b. Includes soil preparation equipment and nitrogen production plant.
- c. Reference case assumed 50 ppb 2,3,7,8-TCDD and 100 ppm 2,4-D and 2,4,5-T. Concentration influences UV photolysis irradiation time requirements to achieve desired destruction.

TABLE 44. SUMMARY OF COSTS FOR DECREASED TREATED SOIL VOLUME COMPARED TO REFERENCE CASE

Cost Category	Reference Case Cost ^a (\$1000)	50 Percent Case ^b	
		Cost (\$1,000)	Percent Change ^c
1. Common remedial	4,187	3,711	-11.4
2. Common operating and monitoring	1,367	1,049	-23.3
3. TD/UV photolysis process setup/removal	1,568	1,568	0
4. TD/UV photolysis process operating and maintenance	<u>4,425</u>	<u>3,046</u>	<u>-31.2</u>
TOTAL	11,547	9,374	-18.8

- a. See Table 41 for subtotals of reference case (20,000 tons).
- b. See Appendix W, Exhibit 2, for category detail breakdown (10,000 tons).
- c. Percent change relates to reference case.

this case with the site reference case. A detailed cost breakdown estimate is shown in Appendix W, Exhibit 2, for the 10,000 tons case.

2. Shipping Costs

Thirty-four pieces are shipped to JI from Oakland, California, and returned (Table 39). Of this number, eight are process pieces and are shipped overland between Tulsa, Oklahoma, and Oakland. Shipping rates, over water in particular, can be volatile. Doubling the shipping costs would increase the unit cost by \$85.6/ton (\$99.6/yd³, a 14.8 percent increase) to \$663.0/ton (\$770.9/yd³). Halving the shipping cost would decrease the unit cost by \$42.8/ton (\$49.8/yd³, a 7.4 percent decrease) to \$534.6/ton (\$621.6/yd³).

3. Fuel Costs

Diesel fuel in the reference case was priced at \$1.00 delivered to JI. The world market conditions could rapidly change the price either up or down. The estimated diesel fuel cost in the reference case was about \$940,000. Doubling this cost, because of either increased consumption or unit price, would increase the unit cost by \$47.0/ton (\$54.7/yd³, an 8 percent increase) to \$624.4/ton (\$726.0/yd³). Halving the fuel cost would decrease the unit cost by \$23.5/ton (\$27.3/yd³, a 4 percent decrease) to \$553.9/ton (\$644.0/yd³).

4. Labor Costs

The total site labor cost for the project, not including per diem or travel, is \$2,125,000. Doubling this cost would increase the unit price by \$106.2/ton (\$123.6/yd³, an 18.4 percent increase) to \$683.6/ton (\$794.9/yd³). Halving this cost would decrease the unit price by \$53.1/ton (\$61.6/yd³, a 9.2 percent decrease) to \$524.3/ton (\$609.7/yd³).

5. TD/UV Photolysis Process Equipment Use Charge

At a monthly rate of \$105,000 for 12 months related to the JI project, the burdened total TD/UV photolysis process equipment charge for the reference case was calculated to be \$1,840,000. Doubling the use charge rate would increase the unit price \$92.0/ton (\$107.0/yd³, a 16 percent increase) to \$669.4/ton (\$778.3/yd³). Halving the use charge rate would decrease the unit price \$46.0/ton (\$53.5/yd³, an 8 percent decrease) to \$531.4/ton (\$617.8/yd³).

6. HO Contamination Level

The reference case assumed an average concentration of 50 ppb 2,3,7,8-TCDD, 100 ppm 2,4-D, and 100 ppm 2,4,5-T, which for 20,000 tons of soil corresponds to 2 lb of 2,3,7,8-TCDD and 4000 lb each of 2,4-D and 2,4,5-T. The desorber capacity and operating costs are not influenced significantly by the quantity of HO contaminants to be removed from the soil; whereas, the UV photolysis system is sized for the quantity of HO contaminants that must be treated. The photolysis equipment capacity and operating costs (other than labor) are nearly proportional to the HO quantity. Doubling the average HO concentration (e.g., 100 ppb 2,3,7,8-TCDD and 200 ppm 2,4-D and 2,4,5-T) in the soil would cause an increase of \$42.1/ton (\$49.1/yd³, a 7.3 percent increase to \$619.5/ton (\$720.4/yd³). Reducing the HO concentration level by 50 percent (e.g., 25 ppb 2,3,7,8-TCDD, 50 ppm 2,4-D and 2,4,5-T) would result in a \$28.2/ton (\$32.7/yd³, a 4.9 percent decrease) reduction to \$549.2/ton (\$638.6/yd³).

7. System Capacity

If soil contained higher than 10 percent moisture and/or higher removal efficiencies were required (e.g., higher than 50 ppb average soil feed or lower than 1 ppb residual 2,3,7,8-TCDD), the overall effect on operating rate for the TD/UV photolysis process sized for the reference case would influence costs because of the longer operational period with

corresponding equipment use charge and labor costs, and some increase in utilities and other consumables. Likewise, if soil conditions permit higher capacity operation, costs will be lower. Assuming a maximum soil feed rate of 13 ton/hour (130 percent reference case), the unit cost would decrease by \$46.0/ton (\$53.4/yd³, an 8 percent decrease) to \$531.4/ton (\$617.9/yd³). The change primarily results from 23 fewer days of operation. For a minimum soil feed rate of 7 ton/hour (70 percent reference case), the unit cost would increase by \$56.2/ton (\$65.4/yd³, a 9.7 percent increase) to \$633.6/ton (\$736.7/yd³). This change primarily results from an additional 42 days of operation.

8. Other Variables

Other assumptions could have a major bearing on site remedial costs, but are only discussed without quantification.

- o Cleanup Criteria: The 1-ppb TCDD level has been applied at residential sites, but may be adjusted to less stringent levels for other exposure scenarios, while still maintaining the same risk target (see Section I.B.1). Because the majority of soil over the site area is slightly above the 1-ppb level, a modification in cleanup criteria will have a substantial impact on overall soil volume and remedial cost.
- o Personnel Protection: The current EPA health and safety protocol requires the use of Level C personnel protection to prevent direct exposure to TCDD-contaminated soil. Buildings and enclosed equipment can usually be provided with suitable filtration devices to protect workers wearing Level D equipment. As shown in Table 45, the level of personnel protection can have a substantial impact on remedial cost. An increase in the number of workers wearing Level C protection or changing to Level B can substantially affect the remedial cost.

TABLE 45. REMEDIAL COSTS RELATIVE TO CONVENTIONAL CONSTRUCTION

Factor ^a	Level of Protection					
	B		C		D	
1. <u>Crew Size</u>						
Productive crew size	10		10		10	
Support team	<u>3</u>		<u>2</u>		<u>1</u>	
Total team size	13		12		11	
Ratio of: <u>crew size</u> <u>total team</u>	0.77		0.83		0.91	
2. <u>Available Work Time</u> (as percent of paid time)						
Moderately cool (65°F)	320 min 0.71		370 min 0.82		420 min 0.93	
Moderately hot (85°F)	220 min 0.49		270 min 0.62		380 min 0.85	
3. <u>Gross Productivity</u>						
Light work	0.8		0.90		1.0	
Heavy work	0.6		0.75		0.9	
4. <u>Net Remedial Productivity</u> = <u>Conventional Productivity</u>						
	0.46 to 0.24		0.61 to 0.37		0.85 to 0.70	
5. <u>Remedial Site Labor</u> = <u>Conventional Labor</u>						
	2.2 to 4.2x		1.6 to 2.7x		1.2 to 1.4x	
6. <u>Cost Impact Multiplier</u> (over conventional costs)						
	<u>65°F</u>	<u>85°F</u>	<u>65°F</u>	<u>85°F</u>	<u>65°F</u>	<u>85°F</u>
for items with 40% labor	1.48	2.28	1.24	1.68	1.08	1.16
for items with 50% labor	1.6	2.6	1.30	1.85	1.10	1.20
for items with 60% labor	1.72	3.12	1.36	2.02	1.12	1.24
<u>PROTECTIVE EQUIPMENT COST</u>						
Purchase	\$52		\$30		\$10	
Disposal	18		18		66	
Monitoring equipment	<u>10</u>		<u>7</u>		<u>7</u>	
Total (\$/d/person)	\$80		\$55		\$23	

a. See General Notes, next page.

TABLE 45. REMEDIAL COSTS RELATIVE TO CONVENTIONAL CONSTRUCTION(CONCLUDED)

GENERAL NOTES TO TABLE 45

1. Based on a 10-man working crew, paid for 8 hours/day, with a support team of 1 to 4 people (depending on protective level).
2. Of a total of 480 paid minutes/day, a portion of each team member's time is spent on suit-up/off, breaks, changing air tanks, and site safety meeting. The following daily time breakdown was assumed:

	<u>B</u>	<u>C</u>	<u>D</u>
Safety meetings	20	10	10
Suit-up/off	60	40	10
Air tank change	20	0	0
Breaks	40-140	40-140	30-70
Cleanup	<u>20</u>	<u>20</u>	<u>10</u>
Net available time			
Moderately cool	320	370	420
Moderately hot	220	270	380

3. Gross productivity ratio is the efficiency for work actually done during a worker's available work time.
4. The ratio of net remedial to conventional productivity is the product of multiplying each of the above adjustments.
5. The ratio of remedial labor to conventional labor indicates the additional labor required to complete a task in protective equipment.
6. The Cost Impact Multiplier for the additional remedial labor (caused by the above productivity losses) results in an 8 to 540 percent cost increase over conventional construction costs, depending on the protective level and the labor/material split for a given cost element. Most conventional cost elements have between a 40- and 60-percent labor component.

F. COMPARISON WITH NCBC REFERENCE CASE

The TD/UV photolysis technology was previously evaluated for treatment of dioxin-contaminated soils at the former HO storage site at the NCBC in Gulfport, Mississippi. The reference case for estimating the cost of full-scale remedial action was also 20,000 tons (Reference 1). These data provide a basis of comparison for remedial action at a remote site in the Pacific Ocean with a relatively easy access site in the contiguous United

States. Data for JI (from Table 41) and NCBC (Reference 1) are presented below for the estimated total cost, cost per ton, and cost per yd³.

^a <u>Cost Parameter</u>	<u>JI</u>	<u>NCBC</u>
Total cost (\$ million)	11.5	8.0
Cost/ton (\$/ton)	577	400
Cost/yd ³ (\$/yd ³) ^a	671	426

a. Because of different measured density per Volume III of Reference 1, the volumes were calculated as 17,200 yd³ for JI and 18,800 yd³ for NCBC.

These data show the JI remedial action is substantially more expensive at \$3.6 million or about 45 percent.

A more detailed cost breakdown is shown in Table 46. All categories show higher costs for the work being done at JI. Category 1 (Common Remedial Costs) shows the largest cost difference at \$1.7 million. Categories 3 and 4 (TD/UV Photolysis Process Setup/Removal Costs and TD/UV Photolysis Process Operating and Maintenance Costs) are next at about \$0.8 million difference for each category.

Shipping costs were a major factor for Categories 1 and 3, with the total cost difference at \$1.5 million. Slightly less than half (\$0.7 million) is involved in shipping the TD/UV photolysis process equipment by water from the mainland to JI. The rest (\$0.8 million) is due to the unavailability of common support equipment at JI, thereby requiring this equipment shipped by water as well. The additional time (5 weeks each way) required to ship the equipment by sea added to the equipment use charges by \$1.3 million. The cost for electricity and fuel to operate the thermal desorber was about \$0.3 million extra. At JI, both were supplied

**TABLE 46. ESTIMATED COST OF SITE REMEDIAL COSTS FOR TD/UV PHOTOLYSIS
TREATMENT OF 20,000 TONS OF SOIL AT JI AND NCBC SITES**

Category	Cost (\$1000)		Percentage Project Cost (%)	
	JI	NCBC	JI	NCBC
1. Common Remedial Costs				
Mobilization	255	209	2.2	2.6
Facilities and utilities	1,273	801	11.0	10.1
Evacuation/site restoration equipment and material	1,130	905	9.8	11.3
Shipping	791	--	6.9	--
Labor	738	567	6.4	7.1
	<u>4,187</u>	<u>2,482</u>	<u>36.3</u>	<u>31.1</u>
2. Common Operating and Monitoring Costs				
Coordination	51	48	0.4	0.6
Monitoring and analysis	960	858	8.3	10.8
Facility operations	356	227	3.1	2.8
	<u>1,367</u>	<u>1,133</u>	<u>11.8</u>	<u>14.2</u>
3. TD/UV Photolysis Process Setup/Removal Costs^a				
Planning and site preparation	165	83	1.4	1.0
Shipping	915	204	7.9	2.6
Labor	374	343	3.3	4.3
Material	114	116	1.0	1.5
	<u>1,568</u>	<u>746</u>	<u>13.6</u>	<u>9.4</u>
4. TD/UV Photolysis Process Operating and Maintenance Costs^b				
Equipment use charge	1,845	1,344	16.0	16.8
Utilities and fuel	886	598	7.7	7.5
Maintenance and materials	637	586	5.5	7.3
Labor	893	923	7.7	11.6
Waste disposal	164	164	1.4	2.1
	<u>4,425</u>	<u>3,615</u>	<u>38.3</u>	<u>45.3</u>
TOTAL	<u>11,547</u>	<u>7,976</u>	<u>100.0</u>	<u>100.0</u>

a. Includes trial burn operation.

b. Treatment of 20,000 tons of soil.

by diesel fuel; whereas, at NCBC, electricity and natural gas for the thermal desorber are both provided by commercial supplies from existing connection at the base.

G. ALTERNATIVE PROCESS CONCEPTS

Based on the estimated costs for a full-scale TD/UV photolysis process, several alternative process concepts have been identified by ITC that offer the potential for cost savings, but would affect the need for offsite disposal and the regulatory approval process. These process alternates would relay on the same thermal desorption system to decontaminate the soil, but would treat the contaminants in the desorber off-gas differently. Each process alternate for off-gas treatment is described briefly with its advantages and disadvantages.

1. Solvent Scrubbing with Isolation of HO Contaminants for Ultimate (Offsite) Disposal

The same basic solvent scrubbing system as described for the reference case TD/UV photolysis system would be used, except no UV photolysis treatment of the solvent would be done. The chlorophenols, PCDD/PCDF, and other HO-related contaminants would be separated from the solvent by distillation, with the more volatile solvent condensed and recycled. The contaminants would be consolidated into as small a volume residue as possible and placed into appropriate containers, to be stored temporarily in an RCRA interim storage facility until an available incinerator was permitted under RCRA to burn PCDD/PCDF waste. Based on the reference case, the volume of residue after distillation is estimated to be approximately 2000 gallons. The primary advantages of this approach compared to the TD/UV photolysis process include (a) a significant reduction in UV photolysis equipment use charge costs (\$45/ton) and utilities (\$17/ton, 400 kW diesel electric generator use charge and fuel) and (b) a simpler process that would require less process

development/demonstration before full-scale implementation, less equipment in the field, and a shorter time period to implement. The cost savings would be partially offset by the hazardous drums procurement, shipping and disposal facility charge costs. The primary disadvantage is the continued disposal requirement for PCDD/PCDF waste and potential regulatory issues.

2. Solvent Scrubbing with Isolation and Destruction of PCDD/PCDF and Offsite Incineration of Other HO-Related Contaminants

Using the same basic solvent scrubbing system, an additional separation step would be utilized for treating the solvent purge before UV photolysis. The step would extract the chlorophenols, which represent 99.97 percent of the reactant load to the UV photolysis system, with the PCDD/PCDFs retained in the scrubber solvent. The PCDD/PCDFs would be destroyed by photolysis, and the chlorophenols would be isolated as a small volume residue for offsite incineration. The advantage is the substantial reduction in capital and operating costs (e.g., electrical power) for the photolysis system and the generation of an organic residue of about the same quantity as the base case but potentially containing no residual PCDD/PCDF, facilitating immediate acceptance by currently permitted incinerators. The disadvantage is the need to develop the extraction separation step, the incremental capital and operating costs for this step, and the potential permitting delays due to a basic modification of the TD/UV photolysis process which has already been demonstrated.

3. Solvent Scrubbing with Chemical Treatment of PCDD/PCDF

Several chemical reagent systems have been demonstrated to effectively dechlorinate PCDD/PCDFs (as well as other polychlorinated aromatic compounds, such as PCBs) in a nonreactive solvent matrix (Reference 38). Chemical treatment, rather than UV photolysis, could be applied to the scrubber solvent purge or solvent residue containing PCDD/PCDF from either the base case TD/UV photolysis process, or alternate processes (1) or (2). Equipment use charges and operating costs would need to be determined based on experimental data; costs could be lower than

photolysis. Offsite disposal of the organic residue, which would contain reaction products, would still be required. Obtaining regulatory approvals might be more difficult because the process has not been demonstrated. However, a similar process was demonstrated in a full-scale trial on a waste oil contaminated with pentachlorophenol and PCDDs. This was an EPA-funded demonstration at Butte, Montana, in July 1986; no report of results has been published yet.

4. Incineration of HO Contaminants

The desorber off-gas could be fed directly to a combustion system to destroy all HO contaminants, eliminating the need for offsite disposal. The quantity of desorber off-gas is very low relative to the flue gas from a conventional direct-fired combustion unit, such as a rotary kiln, which reduces the size and heat duty of the combustion and air pollution control systems. The potential disadvantage is in acquiring an RCRA permit, because this is a different process than was demonstrated in pilot-scale at NCBC. However, effective combustion of PCDD/PCDF has been demonstrated by the EPA's mobile incinerator (Reference 36), and permitting may not be more difficult. The capital and operating costs are expected to be comparable to the TD/UV photolysis base data.

5. Summation

Consideration, evaluation, and selection of any alternate process would require additional laboratory and possibly pilot-scale testing, preliminary process engineering, cost estimating, and investigation of regulatory issues. The potential benefits of certain alternatives are likely tied to the particular site situation and schedule objectives for restoration. The acceptability of alternative (1), for example, will increase significantly once an RCRA-permitted incinerator is approved to accept PCDD/PCDF wastes. Alternative (3) would probably have the shortest development and permitting time frame.

SECTION VII
CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Field Testing

ITC performed a field demonstration of its thermal desorption/ultraviolet photolysis process with dioxin-contaminated soil at Johnston Island, in the Pacific Ocean, by using pilot-scale units. A total of about 2180 pounds of soil were processed. This demonstration was accomplished in July 1986; however, there was significant delay in the initiation of the field work because of the time required to obtain the RCRA R&D permit from EPA Region IX.

a. Soil Thermal Desorption Treatment

The results from both analytical laboratories, ITAS and Battelle, showed that all four test runs treated the coral soil so that the PCDD/PCDF congener sum (tetra through hexa) satisfied the Air Force goal of 1 ppb or less. These results showed that soil feedstock with initial 2,3,7,8-TCDD concentrations of 34 to 57 ppb can be satisfactorily treated by the desorption process with a soil operating temperature of 1022 °F and soil residence time in the furnace section of 5.6 minutes (feed rate of 209 lb/hr for pilot-scale unit). The 2,3,7,8-TCDD removal efficiency was found to be 99.59 to 99.94 percent, depending on test run and analytical laboratory. The removal efficiency for the best performing run compared to the one satisfactory test run by the ITC unit at the NCBC test, which was 99.96 to 99.97 percent.

Organic compound treatment performance was limited to the reduction of HO constituents 2,4-D and 2,4,5-T because PPL volatiles, semivolatiles, organochlorine pesticides, and PCBs were not detected in the soil feedstock. Analytical laboratory results indicate that the removal efficiencies for 2,4-D and 2,4,5-T were at least 99.992 and 99.997 percent,

respectively. The factors are likely higher because DLVs were used in the calculation for the treated soil.

Several volatile organic priority pollutants (notably toluene and benzene) were detected in the treated soil samples at very low levels (≤ 1.1 ppm). A variety of isoparaffins were also detected. The presence of these compounds, which are all constituents of the scrubber solvent, is believed to be caused by the contact of recirculated purge gas with treated soil as it discharges from the desorber. Equipment design changes have been made to correct this problem.

Inorganic concentrations in the treated soil were significantly low so that an EP toxicity test was not needed. A comparison of concentrations in the feedstock and treated soil samples showed no significant difference for the five PPL metals that were detected in the feedstock.

Although not sufficient, the pilot-scale test results support the treated coral being delisted if full-scale restoration of the site employs the ITC thermal desorption technology. This was shown by the reduction of the PCDD/PCDF concentrations below the EPA proposed landfill disposal criterion of 1 ppb, the removal of HO constituents to nondetectable concentrations, and soil characteristics that meet hazardous characteristic requirements in 40 CFR 261.21-261.24. As a minimum, TCLP analysis, VHS model calculations, and additional toxic and hazardous compound screening remain to be done.

b. Scrubber Solvent Treatment

Substantial reduction of PCDD/PCDF concentrations in the treated scrubber solvent was achieved in the single test. However, the sum of the six congeners (1 a through hexa) ranged from 14 to 27 ppb for ITAS results (sample and lab duplicate) to 190 to 198 ppb for Battelle results (also sample and lab duplicate), which are well above the project goal of 1 ppb. The 2,3,7,8-TCDD concentration for the sample was less than 1 ppb

and is an achievement because of its toxicological acuteness. Although the removal efficiency for this isomer was at least 99.90 percent from ITAS data and 99.94 percent from Battelle data, the treated solvent remained a hazardous waste. Resolution of this problem should be accomplished by longer solvent exposure times to the UV light. Treated solvent residues (tars) will probably require offsite disposal as a hazardous waste; reduction of PCDD/PCDF in these residues will be a factor in the availability and cost of such offsite waste disposal.

c. Off-Gas Treatment

None of the PCDD/PCDF congeners (tetra through hexa) was detected in the samples of the activated charcoal filters. Compared to the NCBC results in which small amounts of TCDD, TCDF, and P₅CDF were detected in the samples of the front third of the primary filter, the JI results reflect either lower feedstock concentrations or difference in the sampling procedure.

Large amounts of methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane (constituents of Freon 113) were found in the activated carbon samples and VOST samples. This has been deduced to be due to leakage from supply cylinders of the cleaning agent (methylene chloride) and Freon 113, which were shipped in the same container from the mainland to JI and then stored until the permit process was completed to start testing.

d. Scrubbing Effectiveness

The scrubber removal efficiencies for 2,3,7,8-TCDD and total tetra-hexa PCDD/PCDF congeners were found to be greater than 99.995 and 99.95 percent, respectively. The removal efficiency for 2,4-D and 2,4,5-T and the corresponding chlorophenol decomposition products was 99.98 percent. These results are comparable to those obtained in the NCBC testing.

2. Full-Scale Cost Estimate

A cost estimate of \$11.5 million has been prepared for the excavation, soil pretreatment, and TD/UV photolysis soil treatment of 20,000 tons (17,200 yd³) of dioxin-contaminated coral soil. The unit costs are \$577/ton or \$671/yd³, based on local soil density. The NCBC cost study was used as a reference for generic costs. The concept of operation includes environmental controls (soil wetting, covered soil storage bins) to mitigate release of contaminants during the process. Planned duration from site setup to teardown is about 35 weeks, which includes 14 weeks for a trial burn and data review with EPA Region IX before full-scale soil restoration.

The remoteness of JI was found to be a significant factor. The JI costs for 20,000 tons soil remedial action were estimated to be \$3.7 million more compared to the same remedial action at NCBC. Major factors were (a) ocean shipping (\$1.5 million), (b) equipment use charges related to shipping time (\$1.3 million), and (c) more expensive energy for electricity and thermal desorber operation (diesel fuel, \$0.3 million).

Sensitivity analysis of seven variable (soil quantity, shipping, fuel, labor, TD/UV equipment use charges, HO concentration, and feed rate) shows that soil quantity is the dominant factor, followed by labor, TD/UV equipment use charge, and shipping.

Although the desorber feed rate scaleup is a factor of 100 compared to the maximum pilot-scale feed rate at JI, successful coral soil treatment can be expected based on extensive use of large-scale comparable units for processing solids in other related industries. A more significant factor will be determining sufficient exposure at the operating temperature for large chunks of soil because of time-dependent heat transfer. Previous laboratory testing indicates that chunks up to 2 inches can be processed. The 1/2-inch restriction for the pilot-scale testing was due to hopper screw size limitations and would not apply for the full-scale unit.

The primary scaling factor for the UV photolysis process is the light energy per unit of solvent and is the same for pilot-scale and full-scale operation (4 kWh/gallon). Thus, for increased amount of solvent, more wattage is required to achieve the exposure time. The successful pilot-scale runs at JI and NCBC and previous laboratory tests provide a basis for selection of an exposure time-temperature set of conditions. A more significant concern is selecting the objective of the UV photolysis process: Reduce the concentrations of hazardous constituents to levels no longer considered hazardous or reduce the volume of hazardous waste sufficiently for cost-effectiveness in shipping to and disposal at an RCRA-permitted facility (if available) on the mainland.

B. RECOMMENDATIONS

1. Based on both ITAS and Battelle data, it is recommended that the thermal desorption process be considered as an acceptable technology for treating dioxin-contaminated soils. This process has an advantage because it can process soil and other inorganic solids with little pretreatment and uses conventional equipment. Of particular interest is the fact that this is not a thermal destruction technology and the texture of the treated soil is not significantly altered.
2. The thermal desorption process also should be considered as a technology for detoxifying soils contaminated with other organic compounds that require delisting according to EPA regulations.
3. Based on both ITAS and Battelle data, it is recommended that the UV photolysis process be considered as an acceptable technology when it is used in conjunction with thermal desorption for dioxin-contaminated waste volume reduction. Before contracting this process, however, the objectives for possible concentration reduction should be evaluated for cost-effectiveness. It is also

possible that one of the alternative methods such as chemical reaction discussed in the text would be better and should be considered.

4. For any full-scale remedial action, the precontract phase should evaluate different soil treatment feed rates to achieve a desired balance on cost and schedule effectiveness by this technology.
5. The acceptability of the TD/UV photolysis technology is based on regulations that applied during 1986, when the testing and data evaluation occurred. Anyone considering use of this technology should check the applicable EPA regulations for changes that could impact its use.
6. Before full-scale restoration at the site, it would be prudent to reach delisting agreement with EPA Headquarters before field operations begin.
7. Because of the long delays in obtaining the JI pilot-scale test RCRA R&D permit from EPA Region IX, the project schedule for remedial action at JI should include sufficient allowance of 12 to 24 months to obtain an RCRA Part B permit, which could be the critical path upon contracting the work to be done.